

Training industry needs & Technology Industry needs

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Joint Deliverable

D1.1 & D1.2

Training industry needs & Technology Industry
needs

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Wearable Experience for Knowledge Intensive Training
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Training industry needs & Technology

Industry needs

WP 1 | D1.1, D1.2

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Executive summary

This deliverable joins D1.1 (User Industry Needs) and D1.2 (Technology Industry Needs and Affordances) and reports on the outcomes of Tasks T1.1 (Training Industry Assessment) and T1.2 (Technology Industry Assessment).

We merged the deliverables for the following reasons:

- ◆ For readability ease we have merged the two deliverables D1.1 and D1.2 into one.
- ◆ Saving time and effort, since both issues T1.1 / T1.2 are not independent, we have decided to merge the body of study / analysis (joint questionnaire!) into one, clearly separating out goals (introduction) and recommendations (conclusion) for each of the two tasks.

Despite being merged, this deliverable clearly delivers the expected outcomes of each of the constituents as part of the conclusion:

- ◆ Gather information about current practices in the training industry about the current and potential use of AR/WT in educational processes in order to assess training industry needs (D1.1) and to extract input for the WEKIT Framework and Training Methodology (T1.1).
- ◆ Gather information about current practices in the technology industry about conditions, success factors and acceptance conditions for the current and potential future use of AR/WT in educational processes and other industry relevant use cases in order to assess technology industry needs (D1.2) and to extract requirements for WEKIT scenarios and technical prototype (T1.2).

Our results confirm a high interest in augmented reality (AR) and wearable technologies (WT) for educational purposes, while they also reveal, that the experience with these technologies in practical use is still sparse. To support the development of educational AR/WT applications with a focus on usefulness, usability, and feasibility, we collected a number of insights taking three perspectives: industry needs, user needs, and technology needs.

These insights feed into the parallel deliverables D1.3 (WEKIT Framework and Training Methodology) and D1.4 (Requirements for scenarios and prototypes) and also are used as starting point for the technical and pedagogical workpackages WP2 (Wearables-Enhanced Learning Technology Platform), WP3 (Wearable Experience Capturing and Analytics), WP4 (Augmented Reality Learning and Experience Re-enactment), WP5 (Workplace Integration and Human Aspects). Furthermore, the industrial learning scenarios (WP6) will utilise this deliverable.

1. Introduction

The WEKIT project aims to build a technology platform and methodology to capture expert experience and share it with trainees in the process of enabling immersive, in-situ, and intuitive learning. In this way, WEKIT will bring learning content and technical documentation to life via task-sensitive Augmented Reality (AR), making industrial training more efficient, affordable and engaging.

In an effort to mobilise a community of stakeholders, WEKIT aims to roadmap pathways for the use of Technology-Enhanced Learning in changing industrial landscapes. The technology platform developed in the project (called WEKIT.one) will be based on the analysis of industrial needs and will be validated through user tests. WEKIT aims to enhance human abilities to acquire procedural knowledge by providing a smart system that directs attention to where it is most needed.

To ensure, that the WEKIT projects concepts, developments and prototypes are in line with industrial needs, practices and expectations, this deliverable informs about the activities performed within the first months of the WEKIT project in correspondence to the following tasks:

- ◆ T1.1 Training Industry Assessment (Theoretical Grounding). Surveying AR-based training practice and interviewing stakeholders: perform business analysis, decision analysis, existing and potential applications, business drivers, affordance map and KPIs e.g., for reducing cognitive error, time to complete training task, increased recall, deviation analysis (lead participant: OUNL, contributors: GFT, LT, EA, AL).
- ◆ T1.2 Technology Industry Assessment (Technological Grounding). Surveying AR industry practice and interviewing stakeholders: technology acceptance, including key factors determining success (lead participant VTT, contributors: GFT, OU, UiT, VTT, MP)

This joint deliverable consequently combines the following two deliverables:

- ◆ D1.1 User Industry Needs. Reports the results of the Training Industry Assessment, T1.1. (M7)
- ◆ D1.2 Technology Industry Needs and Affordances. Reports the results of the Technology Industry Assessment, T1.2. (M7)

To get WEKIT's community involvement process started, several measures have been initiated: a community-portal, an online stakeholder survey, a number of individual interviews. This deliverable reports on the online stakeholder survey and the interviews.

Two questionnaire-based surveys have been distributed internally and externally to selected target groups. These questionnaires have been complemented with individual interviews performed with internal pilot partners and external parties.

This deliverable is structured as follows: Section 2 describes the goals underlying this deliverable, section 3 describes the methods applied to surveys and interviews. Section 4 analyses the survey data. Section 5 analyses the interviews. Section 6 concludes the document by highlighting the insights gained from interviews and surveys in a combined form organised according to industry needs, user needs, and technology needs. In the Appendix the original questionnaires and interview questions are displayed.

2. Goals

The activities reported in this joint deliverable support the following goals:

- ◆ Gather information about current practices in the training industry about the current and potential use of AR/WT in educational processes (T1.1).

With this assessment, we aim to gather insight in the training industry's view on the use of AR/WT in educational practice. We aim to identify drivers and barriers to the introduction of AR/WT and to gather potential application cases.

The insights gathered from this assessment help us to derive constituents of the WEKIT Framework and Training Methodology from input gathered in these stakeholder assessments (à T1.3).

- ◆ Gather information about current practices in the technology industry about conditions, success factors and acceptance conditions for the current and potential future use of AR/WT in educational processes and other industry relevant use cases (T1.2).

With this assessment, we aim to elicit the current technological status and expected future developments in order to prepare the elicitation of requirements for scenarios and technological platform (à T1.4).

- ◆ Generally, the assessments aim to involve internal and external stakeholders in the WEKIT community processes.

3. Method

For both tasks (T1.1 & T1.2), we based the assessment on questionnaire-based surveys and on interviews.

We performed two surveys based on questionnaire iterations:

1. The questionnaire for the first survey was designed for experts in the field (internal and external to the WEKIT project)
2. The questionnaire for the second survey was designed as a result of an internal item evaluation procedure based on a long question list with the goal in mind to produce a concise yet valid pool of questionnaire items. The item evaluation has been performed on the basis of distributing the questionnaire to experts within the WEKIT consortium. The final version of the second questionnaire was distributed publicly to gather input from additional participants.

The details for each questionnaire (target group, questionnaire design, participant acquisition process, responses received) are given in the following subsections, followed by the methodological considerations for the interviews.

3.1. First survey questionnaire

3.1.1. Target Groups Addressed

The WEKIT project identified six relevant stakeholder groups to be invited for participation:

1. education & training: researchers and teachers at universities and research organisations.
2. developers: hardware and software developers in the field of augmented reality, wearable technologies and related technology fields.

3. training developers: providers and developers of educational materials, including educational technologies.
4. training providers: organisations other than universities and research organisations providing training to industrial and other institutions.
5. related industries: industries relevant as target organisations for training solutions.
6. public communities, local authorities, and policy makers.

With this variety of target groups included, we aim to include a broad range of different viewpoints covering technology providers, educational technologists, training providers, target organisations, and regulative institutions.

3.1.2. Questionnaire Design

For the first iteration, we decided to design a single questionnaire, which is offered to all different target groups. In order to allow for some specialisation, we ask organisational background questions in the beginning. The questionnaire comprises some optional sections, which are included or excluded based on the organisational background.

The questionnaire is organised in twelve main sections and it contains a total of 57 questions. The questionnaire contains open and closed questions. The questionnaire is structured as follows:

- ◆ The questions in section "Education and training in your organisation" focus on educational processes within the organisation of the participant.
- ◆ The questions about "Educational Content in your organisation" focus on the use of internal and external educational content within the educational processes.
- ◆ The section "AR in Education" focuses on the current situation regarding the use of AR for educational purposes within the organisation.
- ◆ The section "AR Application Perspective" assesses expected future applications of AR.
- ◆ The section "AR technology readiness" aims to estimate the perceived readiness of AR technologies.
- ◆ The questions in "Infrastructure and AR technology acceptance in customer organizations" are focusing on the readiness of infrastructure and readiness of people, i.e. technology acceptance.
- ◆ The section "Interoperability" is asking about the importance of interoperability.
- ◆ The section "Price value" asks about the pricing and benefit of AR.
- ◆ The section "Regulations and conformance" examines the AR-related regulations.
- ◆ The sections "Personal Background" and "Your organisation" ask about the participant and the organisation he/she belongs to.
- ◆ The section "The WEKIT Community" aims to assess a possible relation between the participant and the WEKIT community.

See appendix A1 for full detail about the first questionnaire.

3.1.3. Process

The WEKIT consortium collected a contact base of stakeholders within the identified target groups. A total of 276 persons have been individually invited to participate, of which the majority belongs to groups (1) and (2). In addition, the invitation has been spread to mailing lists, via social media, and as a WEKIT press release.

3.1.4. Responses

We received 31 completely and 23 partially filled out questionnaires (total: 54).

3.2. Second survey questionnaire

Numerous proposals for measuring technology acceptance (and behavioural intention to use) of new information and communication technologies have been made in the past (Venkatesh, 2012; Teo et al., 2010; Schulze et al., 2010; Law et al., 2009; Venkatesh, 2008; Venkatesh, 2003). Metric scales developed can help to assess and predict success and potential success of new developments or even media. Generic models have been elaborated and are in use to assist inception, development, and introduction of new software systems and approaches.

Within this contribution, we first investigate the suitability of such generic models for benchmarking the WEKIT solution. The WEKIT solution is not a conventional software system (desktop software, web, or mobile application), but uses new media, i.e. augmented reality and wearable computing. Moreover, the solution is not applied for home use for leisure or life, but in a workplace context in aviation, space, and health contexts. Both, AR and wearables technologies as well as their application in these work contexts are emerging fields and remain widely unstudied.

Existing studies look either into hardware (Rauschnabel et al., 2015a; Rauschnabel et al., 2015b), regardless of the application, or they are validation studies of effectiveness and efficiency of use (Scavo, 2015), not acceptance.

In order to build a model of what drives acceptance and use of technology in the context of maintenance and repair operations in aviation and space as well as training on operating procedures (of imaging equipment in the health sector), we collect items from existing technology acceptance models.

This includes items from UTAUT (Venkatesh et al., 2003), TAM-3 (Venkatesh & Bala, 2008), UTAUT-2 (Venkatesh et al., 2012), and TPB (Teo, & Beng Lee, 2010), as well as additional items from the generic literature on user experience. We enrich these items in focus groups with technology as well as ergonomics experts with items specific to industry needs.

We will not include questions items on training practice, business analysis, and decision analysis. These will be kept for the qualitative interviews that are reported in a separate section of this deliverable, as these are rather open-ended questions.

As the following section will report, this will result in a pool of 91 statements, many of which belonging to groups of items, investigating the same construct, but asking for different aspects or using different phrases to express the same statement. The statements are formulated in a way so that they can be rated with a 7-point Likert scale, ranging from strongly disagree to strongly agree, including a neutral 'neither agree or disagree' in the middle.

This results in a pool of items to draw from, too big to ask for from participants in the target groups directly (a set of 15-20 would be appropriate).

In order to test reliability and measure internal validity of the model, we ask 15 subject matter experts from within the consortium partnership to provide ratings for all items of the pool.

In the next step, we measure the correlation (Pearson's r) across the responses with the sum scores of all items to assess that each item is actually measuring what we are interested in, testing for

discriminatory power of the item (Diekmann, 2002, p. 244). The general assumption of this is, so Diekmann (2002), that the chance for error is in total less likely than with a single item.

If responses to an item do not correlate with the sum scores of all items' responses, then it is very likely to not measure aspects of acceptance and use of technology, but rather something else. This analysis step will allow sorting out those items not correlating high with the sum score.

Subsequently, we calculate the item to item correlations to identify further items contributing to the same construct. If the correlation between two or more items is high, one or a subset can be selected.

Finally, Cronbach's α will be measured to estimate interrater reliability, comparing the reliability for the full pool as well as the final subset selection.

3.2.1. Item reduction

The pool of 91 statements (and six different types of usage frequencies) were rated by the board of 15 subject matter experts using a 7-point Likert agreement scale each.

The data table lists participant responses (rows) against items (columns), containing numeric value from 1 (strongly disagree) to 7 (strongly agree). For the first analysis step, sum scores for each row were calculated and each item vector was correlated with the sum score vector using Pearson's product moment coefficient r .

Results show that there are several items, that do not correlate (directly or inversely) with the sum score (see Figure 1): there are 12 items in total correlating with the sum scores on a level higher than 0.7, a total of 36 items on a level higher than 0.6, and 45 items with a correlation value higher than 0.5.

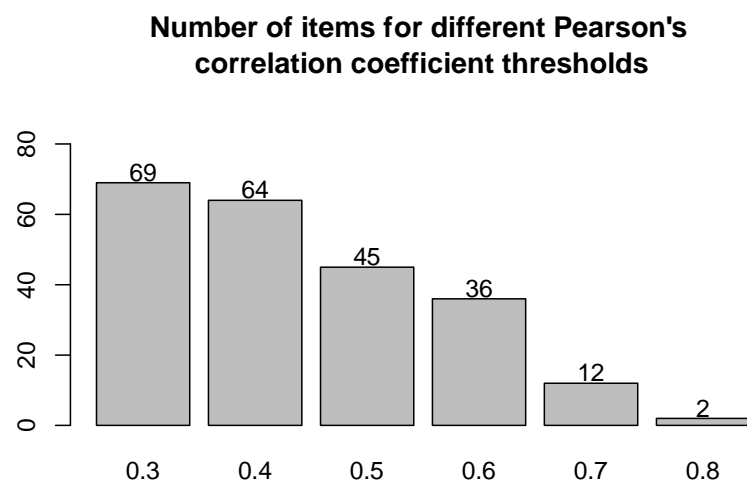


Figure 1. Number of items for different correlation thresholds.

Since the sum scores are composed of all items, including items that may not directly measure what we intend to investigate, we decided to select a threshold of 0.6 of the absolute correlation as acceptable for identifying whether items are on scope. The sum scores indicate that the other constructs either measure something completely different or are not independent of other influences.

Next, we turned to item to item correlations and their groupings. Figure 2 indicates visually that there are groups of items that are related, as expected since we adopted several groups of items from the existing technology acceptance models. The figure displays the correlation matrix (Wei & Simko, 2016) of the items graphically, indicating the correlation value via the size (area) of the circles and additionally colour shade as well. The order of the items in the plot is determined using a hierarchical cluster analysis (hclust, package: stats, R core team, 2016), so items close to each other along the diagonal are tend to correlate more highly.

The triangles visible along the diagonal (and the rectangles within) in the figure indicate that there are groups of items belonging more closely together. This confirms already visually, that there are indeed groups of questions amongst the 36 items selected for a sum score correlation of 0.6 that may load on the same aspect. This potentially will allow picking just one of the items in each group (instead of posing all of them).

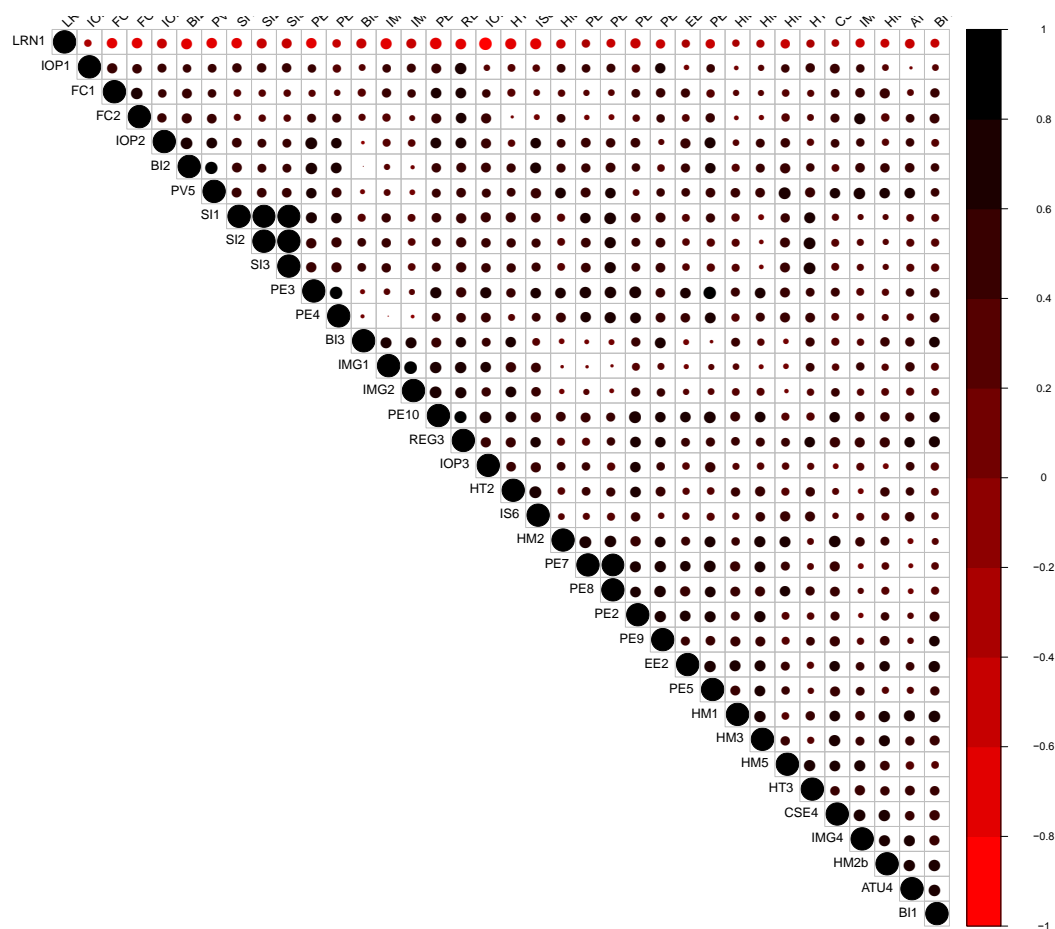


Figure 2. Item to item correlations (selected 36 items).

Detailed analysis of the item groups is provided in Table 1.

Table 1. Item grouping (grey background: selected).

ITEM	COR	ANALYSIS
ATU4	0.63	Better question compared to the two items before, as this is future oriented (and not about past exposure)
BI1	0.71	Expected to group, but inter item correlations (0.4, 0.6, 0.01) is not very strong. Preference for BI2 over BI1/BI3, because it is not dependant on current use of AR/TW.
BI2	0.69	
BI3	0.6	
CSE4	0.71	Covers the other three CSE items, no need to ask the other (less well working) questions. The other three items are more about supports that may not be in line with modern software design approaches (self-explanatory, no need for extended IT support, etc.).
EE2	0.61	This question works best amongst this group of EE items and clearly loads on sum scores. More technical than the other questions - good in our technology context.
FC1	0.65	These two items are working well, no need to ask the other FC items (correlate with 0.74, keep FC1 as it is the more broadly formulated one).
FC2	0.62	
HM1	0.63	Expected that we can only ask one of these HM items - they are very similar.
HM2	0.61	
HM2b	0.67	
HM3	0.63	
HM5	0.67	Badly phrased, drop.
HT2	0.7	Two of the four HT items correlate with sum scores. HT2 and HT3 correlate with 0.5, but HT2 is better formulated (less bound to previous exposure).
HT3	0.72	
IMG1	0.65	Three of the four IMG items correlate higher with the sum score. Expect two more to drop out with group analysis: IMG1 vs. IMG2: 0.91, so keep IMG1.
IMG2	0.62	
IMG4	0.69	
IOP1	0.66	Three of the 10 IOP items correlate highly with sum scores. Integration questions about existing integration could not be answered. Questions about content / content experience could not be answered. Maybe end-users do not see this separation between content and system as we do. IOP1/2/3 do not correlate (0.45, 0.23, 0.57). Drop IOP1, as interoperability is a difficult word.
IOP2	0.64	
IOP3	0.68	
IS6	0.69	Only item left in this group.
LRN1	-0.78	<i>Reverse item.</i>
PE2	0.71	Very close, pick PE4 as it is more different from the other PE items.
PE3	0.74	
PE4	0.62	
PE5	0.69	

ITEM	COR	ANALYSIS
PE7	0.6	These are novel, AR/WT functionality related questions. The task completion questions can be grouped. Reduce error and increase precision express the same.
PE8	0.65	
PE9	0.73	
PE10	0.87	
PV5	0.74	Drop this question: out of context, cannot be interpreted anymore without the other PV items.
REG3	0.87	Should have been an inverse item, but isn't, so: drop.
SI1	0.71	Similar, picked one of the three well loading items.
SI2	0.7	
SI3	0.7	

Investigating the items not in the 36-item selection (with correlations to sum scores above 0.6) shows the following particularities.

Anxiety (group CANX) does not correlate with the sum scores. This may have to do with the selection of our test participants. This group of items is likely to be more relevant in an everyday use context and it may not be so relevant in a work context. Workers also may prefer management by objectives that are way within their capability. We can't separate whether anxiety would be personal or work related and this is better to explore qualitatively in an interview context, in which we can separate between personal use and work use (and the anxieties connected to it).

Questions about management support (such as DM1) are too early to ask, as in most contexts right now AR/WT are in prototype or exploratory use (if at all) and such question would need real exposure in daily routine.

Questions about integration with legacy systems do not work. This is likely to have to do with competence of people asked, as system integration is not their job, nor within their knowledge. Similarly, the lack of exposure or exploratory use of AR/WT is a problem among this group of questions.

The question about appeal of the workplace to younger people is out of place: respondents may not know this.

Questions about content and content experience (in dropped items in IOP) could not be answered. Maybe end-users do not see this separation between content and system as we do.

The lack of correlation with sum scores of questions on privacy may be a result of lack of exposure (or infrequent daily use). Questions also do not differentiate by target group of data (and their level of exposure), this would have to be further specified.

The target group cannot answer statements on value for money.

For both the full pool as well as the selected 36 items, the standardized Cronbach's α , as a measure of internal consistency, is similarly high (0.96 for the full pool, 0.97 for the 36 items).

3.2.2. Final questionnaire

Table 2. Final metric scale.

Code	Statement
ATU4	I look forward to those aspects of my job that require me to use AR & WT.
BI2	I will always try to use AR & WT in my daily life.
CSE4	I could complete a job, if I had used similar technologies before this one to do the same job.
EE2	My interaction with AR & WT is clear and understandable.
FC1	I have the resources necessary to use AR & WT.
HM2b	I like working with AR & WT.
HT2	I am addicted to using AR & WT.
IMG1	People in my organization who use AR & WT have more prestige than those who do not.
IMG4	I use AR & WT solutions, because I want to be a forerunner in technology exploitation.
IOP1	Interoperability is important for AR & WT.
IOP2	I am worried about vendor lock in with AR & WT.
IOP3	Integration costs of AR & WT with other software systems in use are high.
IS6	I would find it useful if my friends knew where I am and what I am doing.
LRN1	Learning curve for AR & WT is too high compared with the value they would offer.
PE10	With AR & WT, I immediately know when a task is finished.
PE4	Using AR & WT increases my productivity.
PE8	AR & WT increase precision of tasks.
SI1	People who are important to me think that I should use AR & WT.
UF1	Please choose your usage frequency of AR/WT

3.3. Interviews

The interview method was used in addition to the questionnaires. The reason for the use of interviews was to deepen and expand the understanding on the questionnaire topics and to collect concrete ideas related to for example training goals, desired AR-solution and use cases. The aim was to collect more descriptive information compared with the questionnaires. As the questionnaire (first version) included many open-ended questions on certain topics which were only answered by a minor group of participants, the interviews served as a supplementary data collection method as well.

3.3.1. Qualitative semi-structured interview

The major forms of qualitative interviews are semi- and unstructured interviews. In this study, a *semi-structured interview* method was applied. In a typical semi-structured interview the researcher has a list of questions or series of topics they want to cover in the interview, but there is flexibility in how and when the questions are put and how the interviewee can respond. The interviewer can probe answers, pursuing a line of discussion opened up by the interviewee, and a dialogue can ensue. In general the interviewer is interested in the context and content of the interview, how the interviewee understands the topic(s) under discussion and what they want to convey to the interviewer. Basically these interviews allow much more space for interviewees to answer on their own terms than structured interviews, but do provide some structure for comparison across interviewees in a study by covering the same topics, even in some instances using the same questions (Edwards & Holland, 2013).

3.3.2. Interview topics and questions

The topics for the interview were derived from the first version of the questionnaire. “Use case” was added as a new topic in order to collect ideas and comments for the development of WEKIT use cases. The topics and main question are presented in Table 3. (See Appendix B.1 for full details about the topics and questions.)

Table 3. Interview topics and main questions.

Interview topic	Main question(s)
Personal / company information	<i>What is your role in this organisation, what are your duties at work</i> <i>Please describe your organisation in terms of number of employees, field of business, innovation focus.</i>
[Introduction video]	
Current use of Augmented Reality	<i>Can you please describe, how is AR used in this organisation?</i> <i>Alternative: Can you please describe, how is AR used in your <u>customer</u> organisations?</i>
Educational needs	<i>What is the current status of Augmented Reality in your company's <u>or customers'</u> training and training programmes?</i>
AR technology readiness	<i>What are the main technological problems when using Augmented Reality?</i>
Technology acceptance – performance expectancy	<i>Why would Augmented Reality be great for training / other purposes?</i> <i>How would you justify the necessary investment for AR solutions?</i>
Use case	<i>What do you think of this idea, how could it be better?</i>

4. Analysis of Questionnaire Data

This section analyses the response gathered in the two surveys. We will discuss the quantitative and qualitative data for each survey individually.

4.1. Quantitative and Qualitative Data Survey 1

4.1.1. Education and training in your organisation

The first section asks about the current educational situation in the respondent's organisation. The majority of participants work for organisations with a large number of trainers (more than 200) and a likewise large number of learners (more than 500) (Figure 3 a, b). In most organisations, training is organised with traditional contact courses, but E-Learning offers also play an important role. Internal learning conferences and blended learning/mixed mode have been added as additional options by participants (Figure 3 c).

Technological support for educational processes is mainly given in the form of E-Learning contents and learning management systems. To a smaller extent, simulations and learning games are used, where Maintenance Trainer Simulators, Full Flight Simulators, and Virtual Maintenance Simulators have been added as additional technical support means. So far, AR & WT only play a minor role in organisational education (Figure 3 d).

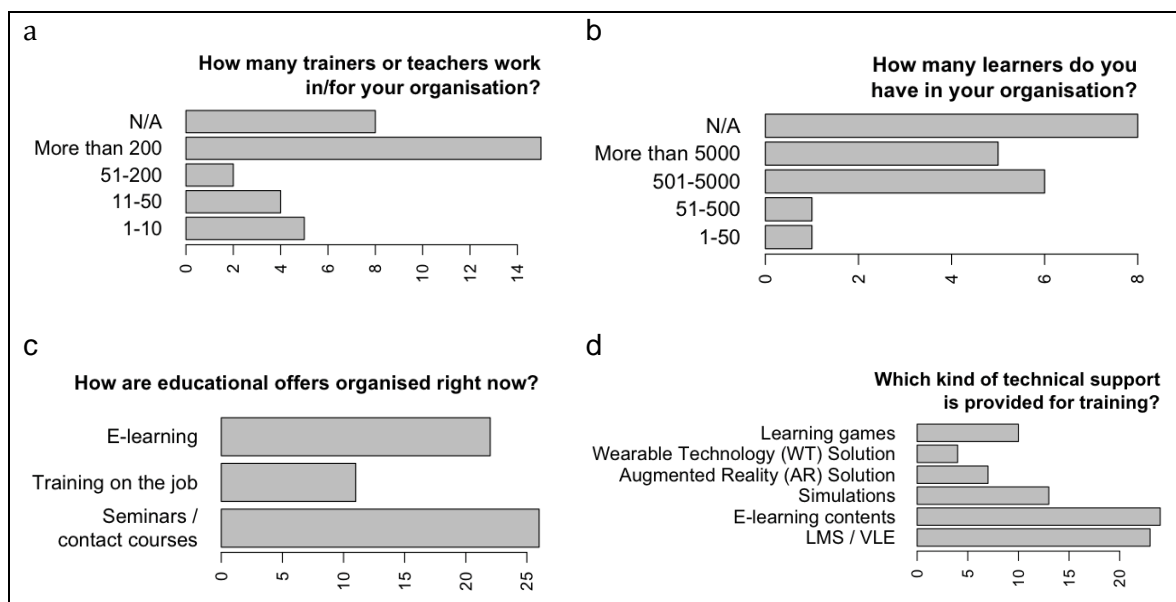


Figure 3. Education now

Participants see potential in AR/WT applications in the fields of health care, activity monitoring, remote training (reduction of travel cost and time), language learning, remote laboratories, device handling, authentic training in real world settings, or the inclusion of hands-on experiences in theoretical courses.

Bottlenecks and main challenges identified include the complexity of content creation and its regular updating and fast changing pace. Additionally a gap between standardised classroom training and context-specific training is observed. Improving training performance by providing more realistic experiences is a major challenge. Also, the production of interactive content apt for AR/WT is seen

as major challenge. Initial efforts and time needed to create AR solutions is also seen as a bottleneck (Table 4).

However, the majority of participants plans to invest in AR & WT alongside investments in general educational technology, while investment in trainers or external providers are only planned to a small extent. Some participant organisations don't plan to invest further. Investment in adaptive training has been added to the list (Figure 4 b).

Mostly internal trainers and individual departments are responsible for the design of the trainings. Management, Human Resources, and external trainers are involved to a smaller extent. Lecturers, the learner himself, and untrained assistants have been added to the list (Figure 4 a).

Table 4. Bottlenecks in training workflow

What are the problems/challenges/bottlenecks in the current training workflow and how could augmented reality and wearable technologies help? (Open Text)

- The use of wearables could help to improve the healthcare or allow monitoring activity of the workers.
- Expanding training and education into fields that are not traditionally approached via e-learning.
- I am not sure what their current challenges actually are but I can make some assumptions. First, they are responsible for training our customers. Travel can be costly for customers so remote training would be valuable. I also believe that if we add AR experiences in place of or in addition to traditional technical documentation then less formal training will be needed. The AR experience will serve as OJT. The Boeing and ISU study reported almost zero errors for first time tasks when instructions were delivered via an AR experience.
- AG could be a useful complement when Learning a new language. For example SFI (Swedish for immigrants)
- The major bottlenecks today include cost and complexity of content creation. This justify the adoption of VR/AR and Wearable Technologies for training especially for high risk or complex operations.
- providing content at scale and in the context it is needed
- It takes to much time to develop courseware, and the commuting of people between the work site and training site. AR/WT could help in increase the development speed and less travelling.
- Integration of Location-based/AR approaches with Learning Management and Certification programmes
- many courses (@university) do not include hands-one experiences - this could be included with AR
- A major challenge is to source or develop or update e-content or AR content for our trainees to help them to bridge the gap between the generalised training that we can offer them in a class setting (for example that we offer for aircraft maintenance or nuclear engineering or semiconductor manufacture), and the context-specific training and certification that high-tech employers seek but which varies from employer to employer and which may change fast.

- My organisation provides courses for Pilots and Maintainers who operate on Helicopters. These courses are certified by International Aeronautical Authorities and they include theoretical parts performed in the classrooms or with e-learning systems and practical parts supported by simulators (maintenance and flight). The main challenge is to improve the performance of the training aids in order to provide trainees with more and more realistic experience.
- A stable platform for AR solutions
- AR and WT can support authentic training and learning in real world settings.
- AR & wearable technologies could help by adding a layer of realism to simulations
- Augmented Reality could be used to reduce the costs inherent to the use of Laboratories in Engineering Education. I am talking about the use of Remote Laboratories for economies of scale.
- Problem: Workload; Help of Wearable Tech: In place, situated learning and not afterwards when time allows for
- Course materials are often still quite dry, text-based and lack concrete examples. Augmented reality would allow to grasp certain concept and principles in interactive augmented reality scenarios.
- In some cases there are topics about abstract concepts and in other there could be lack of devices to train.
- Could help in training the handling of devices like 3D scanners, UAVs, etc.
- Challenges / bottlenecks are these: - Training takes place on the target systems - Preparation of AR is time consuming / causes large initial efforts

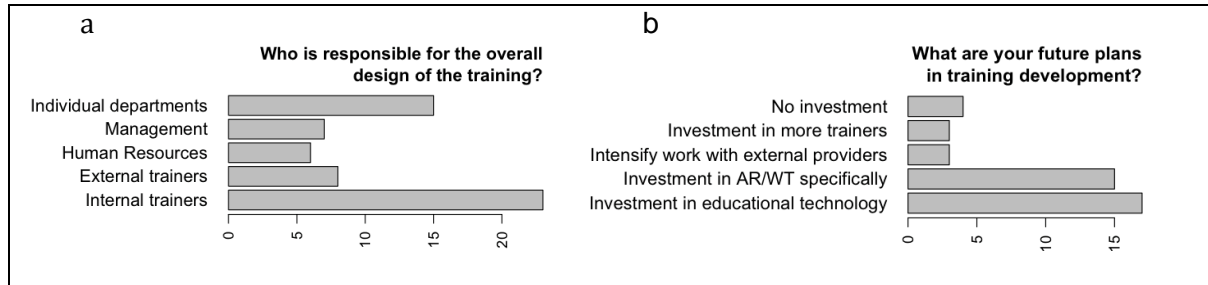


Figure 4. Future plans and responsible persons

4.1.2. Educational Content in your organisation

The use of educational content is dominated by printouts, scripts, books, and e-learning contents. Wikis/blogs, simulations, learning games, and mobile learning contents are also used. AR & WT applications currently only play a minor role in educational content. Hands on training sometimes replaces educational content (Figure 5 a). With respect to standards, SCORM (ADL, 2001) clearly dominates the market. The AR/WT focussed ARLEM standard is not yet represented significantly (Figure 5 b). One participant added XAPI/CM15 to the list of standards, one participant states that their learning syllabus complies to EASA regulations (Table 5).

Content is mainly developed by in-house experts and trainers/lecturers (Figure 5 c). As learning objectives participants state knowledge transfer, awareness, mentorship, practical skills, procedural knowledge, theoretical knowledge, employability, attitude, competence, and team skills (Table 5).

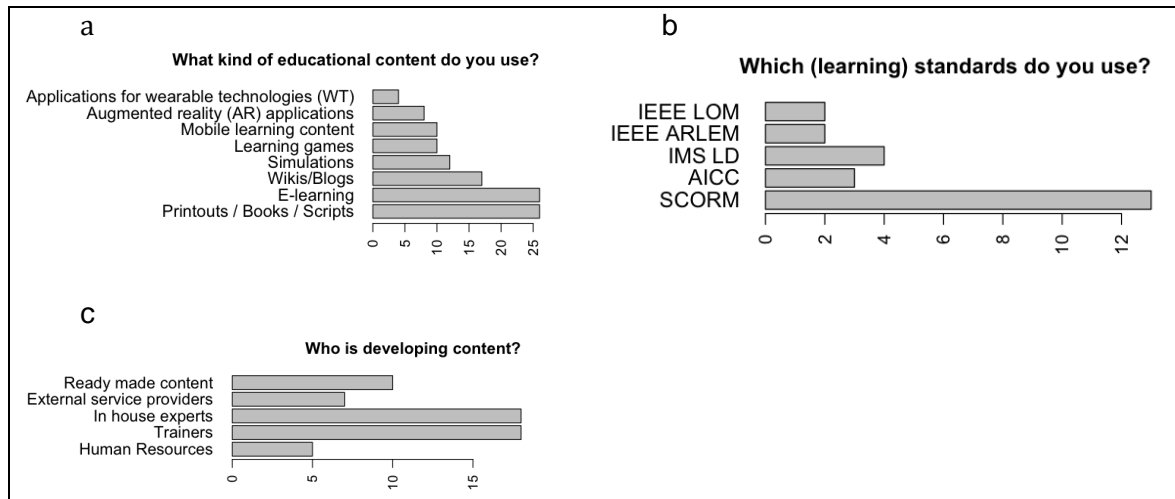


Figure 5. Educational contents and standards

Table 5. Learning objectives

Which learning objectives are you targeting?

Think of e.g.: practical skills, theoretical concepts, procedural knowledge, knowledge transfer. (Open Text)

- knowledge transfer
- Theoretical concepts and practical skills
- Various
- Awareness, knowledge, application, mentorship
- We train in all of these areas depending on the course and target audience. The course could be targeted at installers and the lessons would be mostly practical skills and procedural knowledge. The course could be for release managers, engineers and planners and could be a knowledge transfer for a large upcoming software release. Another course could be for RFI engineers and could teach theoretical concepts.
- Practical and language skills, theoretical contents such as mathematics and also knowledge transfer (internally and externally)
- deep professional skills, employability skills
- Knowledge, practical skills and attitude in combination to gain sufficient competence.
- Higher order practical and professional skills and competences. Application areas: primarily Engineering, Architecture and Management
- theoretical concepts and first hands-on experiences / project-based
- transfer of skills to practise
- All of those objectives are relevant to us, because we are creating tomorrow's knowledge-intensive workers, such as engineers and skilled technicians
- Practical skills, theoretical concepts, procedural knowledge, basic knowledge.
- team communication
- All kinds
- Predominantly theoretical concepts, procedural knowledge
- I am targeting an educational platform that prepares well the learner to be ready for the job. Currently there are gaps between the theory and the actual practical skills the learner gains to do the job in a real world.
- practical skills, procedural knowledge
- Both theoretical and practical skills in computer science.
- all the above
- procedural knowledge and knowledge transfer

4.1.3. AR in Education

The following graph display the answers to the rating question "Drivers to adoption: What do you think would justify the investment necessary to put in place Augmented Reality systems in your organisation?" (see Table 6, Figure 6, and Table 7).

The most relevant topics according to the participants are: lowering costs for task performance, faster task completion, reduction of errors, increase of precision, integration with existing solutions, and increase of workplace appeal to younger employees. Approval of management and co-workers is also indicated as relevant.

Participants were rather indifferent on acceleration of electronic work instructions, lowering training needs for new tasks, immediately knowing when a task is completed, and increasing compliance.

Participants added time needed for training, increase of e-learning portion, increase of student experience, higher return on investment for ICT, improved effectiveness and efficiency, and increased work satisfaction to the list.

Table 6. Drivers to adoption: items

Variable	Description
s1	Accelerates introduction of electronic work instructions.
s2	Lowers cost of performing the tasks.
s3	Serves faster task completion.
s4	Lowers need for training on new tasks.
s5	Immediately knows when the task (test) is finished.
s6	Increases compliance.
s7	Reduces error.
s8	Increases precision.
s9	Integrates well with other systems already in use.
s10	Has approval of management and co-workers.
s11	Increases appeal of our workplace to younger employees

AR in Education: Drivers to adoption

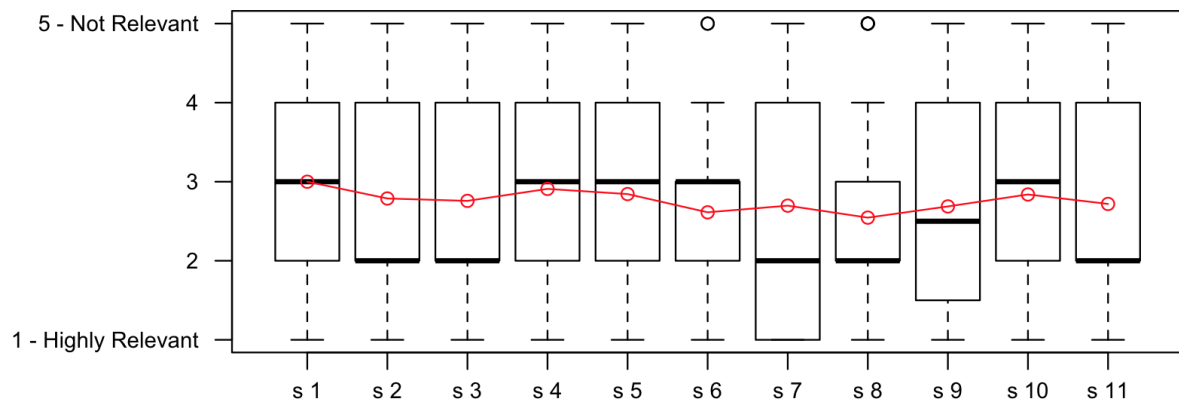


Figure 6. Drivers to adoption

Table 7. Additional drivers
Can you think of additional drivers? If so, please list them here!
(Open Text)

- Enables more learning content to move to e-learning.
- Less time off the job for technicians being trained (when they aren't working the company is losing money). Again, this training is delivered to our customers not within our own organization.
- better student experience.
- Increasing the return on investment in existing ICT. For example all HCT learners have iPads; HCT needs more AR and e-learning content that could run on the iPads.
- Students interest.
- Improves effectiveness and efficiency of work, as well as satisfaction of employees.

The following graphs display the answers to the rating question "Barriers to adoption: What would prevent you from using Augmented Reality (AR) / Wearable Technologies (WT) in your organisation?" (see Table 8, Figure 7, and Table 9).

As relevant barriers participants classified high customisation costs, lack of standard solutions, lack of IT-support, insufficient precision of the technology, lack of integration with existing solutions, and missing offers from standard suppliers.

Participants are indifferent about handling issues of devices while performing tasks, high learning curves, negative past experiences, lack of experience, and compliance of devices and software with policies and regulations.

Infrastructural requirements, accessibility issues and information security concerns are listed as additional barriers.

Table 8. Barriers to adoption: items

Variable	Description
rs1	Can't hold the tablet while performing tasks (I need to use hands)
rs2	Learning curve is too high compared with the value it would offer
rs3	High cost of customization of systems
rs4	Lack of standard, off-the-shelf solutions
rs5	Negative past experiences with similar technologies
rs6	Lack of experience with similar technologies
rs7	Lack of IT support for this technology
rs8	Insufficient precision and/or resolution of the technology
rs9	Not integrated with other systems already in use
rs10	It's not currently provided by the manufacturer of equipment
rs11	Devices and software not certified or compliant with workplace policy or regulation
rs12	Concerns in using AR/WT with respect to content
rs13	Concerns in using AR/WT with respect to target groups

AR in Education: Barriers to adoption

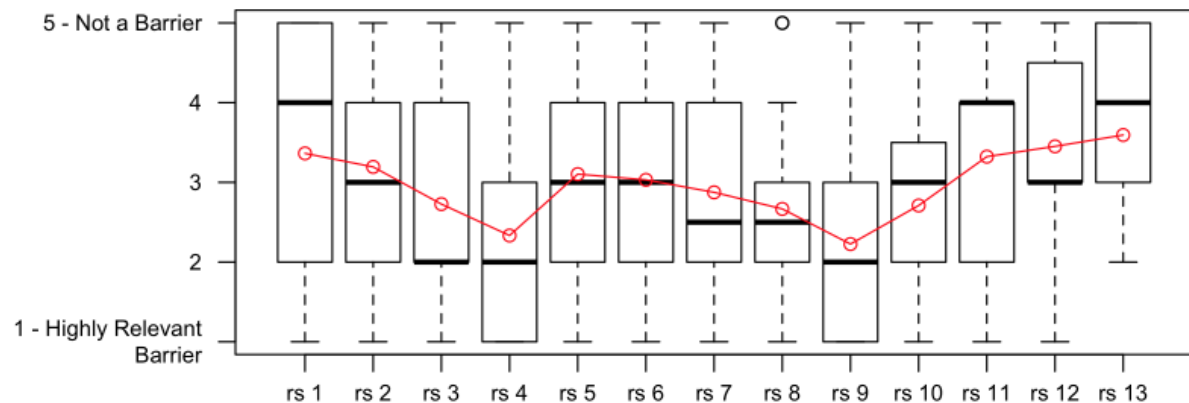


Figure 7. Barriers to adoption

Table 9. Barriers to adoption: additional answers

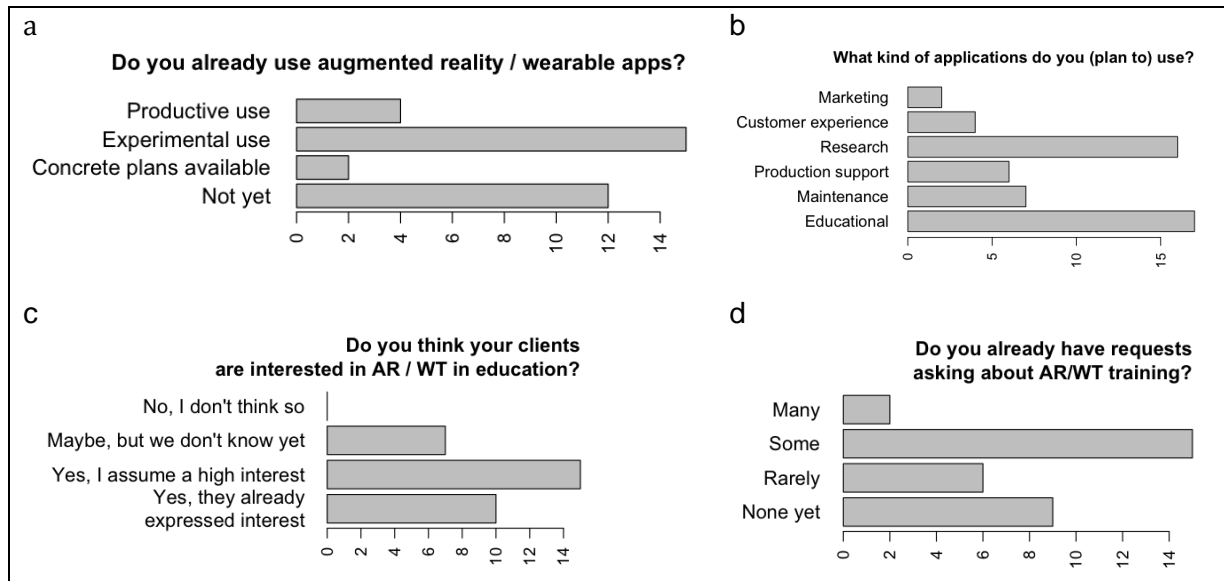
Can you think of additional barriers? If so, please list them here! (Open Text)

- My company or our customers' companies may have concerns over security of proprietary information stored and retrieved from the cloud or on insecure devices.
- Accessibility.
- Additional infrastructure requirements for the organisation.

4.1.4. AR Application Perspective

Participants mainly have AR/WT in experimental use or don't use it at all currently. Productive use or concrete plans are sparse (Figure 8 a). Regarding applications, research and education dominate, followed by maintenance and production support. Marketing and customer experience only play a minor role (Figure 8 b). Participants add customer technical documentation for installation, maintenance, upgrades, troubleshooting, entertainment, tourism, inventory, lab audits, remote technical support, product introduction testing, high-tech maintenance, medical simulations, remote laboratories, interaction with real spaces, marketing & sales, and machine assembly to the list of potential application cases (Table 10).

The majority of participants assumes a high interest in their customer base for educational AR/WT solutions or this interest has already been stated (Figure 8 c). However active requests for concrete AR/WT training are still sparse (Figure 8 d).

**Figure 8.** Application perspective**Table 10.** Application perspective: additional answers
Which potential application areas (domains) can you foresee for the future? (Open Text)

- Entertainment, Tourism.
- Technical customer documentation, training, manufacturing, parts (order fulfillment, etc. not sure of the actual name), inventory, lab audits, remote technical support, field trials, new product introduction testing.
- Manual work support, Maintenance, Remote support, diagnostics.
- Training and production.
- Training, learning.
- High-tech maintenance, for example in our airports, nuclear industry, ethylene plants and aluminium smelting.
- Support of Maintainers on the field.
- Education & Training.
- We are collaborating with nursing school's simulation center to add another layer of realism to their medical simulations.
- Remote Laboratories Knowledge transfer from the Master People with Disabilities.
- If not covered by customer experience, personal entertainment is missing.
- interaction with real spaces out of school.
- Marketing & Sales Production planning Machine Assembly Maintenance work.

The following graph displays the answers to the rating question "Affordance Map: which of the following are relevant application cases for augmented reality (AR) / wearable technologies (WT)?" (see Table 11 and Figure 9)

As most relevant application cases participants rated task orientation, contextual information, maintenance, repairs, operations, DIY guides, and education and training. Less relevant application cases are assembly, inspection and testing, innovation and design, and marketing.

Participants are rather indifferent about career development, technical documentation, and customer experience.

Table 11. Affordance Map: items

Variable	Description
am1	Task orientation
am2	Contextual information
am3	Maintenance
am4	Repairs
am5	Operations
am6	Assembly
am7	Inspection and testing
am8	Career development
am9	Technical documentation
am10	DIY Guides
am11	Education and training
am12	Innovation and design
am13	Customer experience
am14	Marketing

Affordance Map: Relevant AR/WT Application Cases

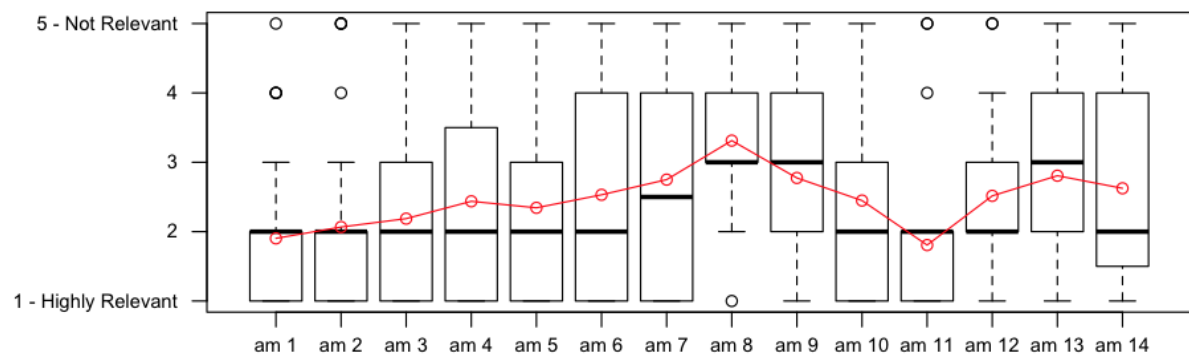


Figure 9. Affordance Map

4.1.5. AR Technology Readiness

The following graphs display the answers to the rating question How technologically ready are the specific AR / WT components to be used by your customers for “work activities?” (see Table 12 and Figure 10)

Participants trust that AR tracking with computer vision and AR delivery on tablets and smartphones are technologically quite far developed, while 3D depth sensing, AR delivery on smart glasses and AR software platforms are a lot less mature. Participants add AR ready data sources on a medium level of readiness to the list.

Participants also listed a number of potential killer applications for AR/WT, including: UI for interactive classrooms, real-time diagnostics in maintenance, remote support, low-cost data

overlays, context-aware personalised systems, and indoor/outdoor military operations HUD (Table 13).

Technological bottlenecks listed include: maturity of technological platforms, standardisation, usability, lack of interoperability, missing unified workplace models, prices for hardware, educational design (Table 14).

Table 12. Technology Readiness: items

Variable	Description
tr1	AR tracking with computer vision
tr2	3D depth sensing
tr3	AR delivery on smart glasses
tr4	AR delivery on tablets
tr5	AR delivery on smart phones
tr6	AR software platforms (e.g. Unity3D).

AR Technology Readiness

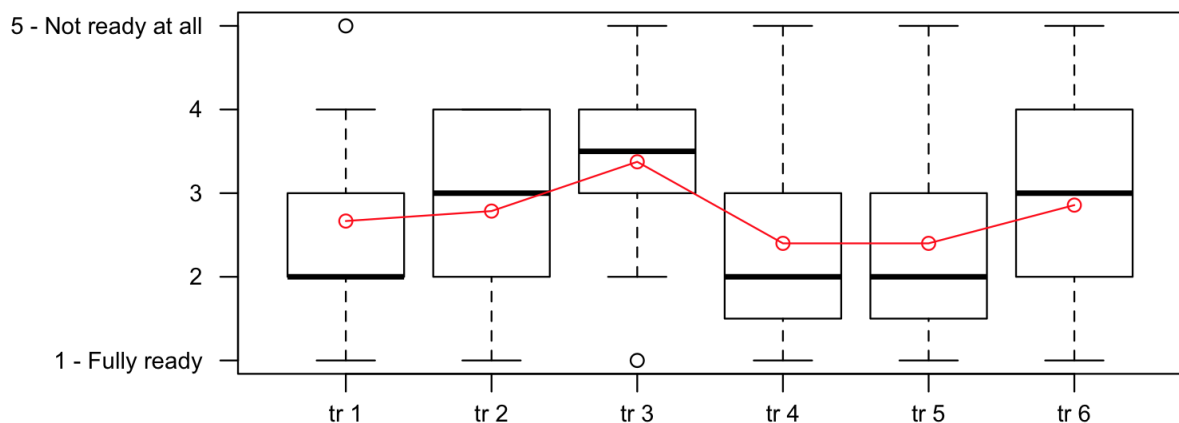


Figure 10. Technology Readiness

Table 13. Killer Applications

In your view, what is the "killer" application for Augmented Reality (AR) / Wearable Technologies (WT)? (Open Text)

- UI for interactive class room - virtual/physical interface.
- Maintenance with realtime diagnostics and remote support.
- Depends on the faculty.
- Low-cost data overlays.
- Stability and ease of use.
- Context aware and personalized adaptive systems.
- Microsoft Hololens.
- indoor/outdoor navigation military operations HUD.

Table 14. Technological Bottlenecks

From your perspective, what are the main technological bottlenecks (software, hardware) for exploiting Augmented Reality (AR) / Wearable Technologies (WT)? (Open Text)

- Technology platforms are not yet mature enough, also challenges related to standardisation etc.
- Usability of devices specially goggles.
- lack of interoperability prevents production of content at scale; lacks in sensor fusion; lacking use cases; missing unified reference models for workplace; smart glass hardware expensive and just good enough.
- Integration with Learning Management Systems via SSO solutions.
- Educational design.
- Task monitoring and feedback.
- Content preparation.
- High cost and barriers to access.
- High prices and low availability of appropriate Hardware and Software. However, this is a swiftly moving market and thus receives a lot attention from research, industry, and private persons.

4.1.6. Infrastructure and AR technology acceptance in customer organizations

The following graphs display the answers to the rating question „Firstly, let us think about infrastructure and technology acceptance about Augmented Reality (AR) / Wearable Technologies (WT) in your customer organizations.“ (see Table 15 and Figure 11).

Table 15. Infrastructure and Technology Acceptance: items

Variable	Description
ita1	Our customer organizations have the resources necessary to use AR/WT
ita2	Our customer organizations have the knowledge necessary to use AR/WT
ita3	Integration of AR/WT into customers organizations' work processes is easy
ita4	Learning how to use AR/WT is easy for our customer organizations
ita5	Our customer organizations need our technical support to be able to use AR/WT
ita6	AR/WT often creates a "wow"-effect in our customer organizations
ita7	AR/WT is often considered as a futuristic technology by our customer organizations
ita8	Our customer organizations use AR/WT solutions because they want to be forerunners in technology exploitation
ita9	The end-users are often involved in the design process of AR/WT solutions

Participants assume, that their customers have the resources necessary to use AR/WT. They expect, that AR/WT solutions can create „Wow“-effects, are considered to be futuristic and enable customers to be forerunners.

Participants estimate, that customers don't have the necessary knowledge to use AR/WT, that introducing AR/WT at customers is not easy and thus technical support will be required to introduce

AR/WT at customers. Participants mainly aim to involve end-users in the design of AR/WT solutions. One participant fears that their customers are unaware of the potential of AR/WT in their domain.

AR/WT Infrastructure and Technology Acceptance

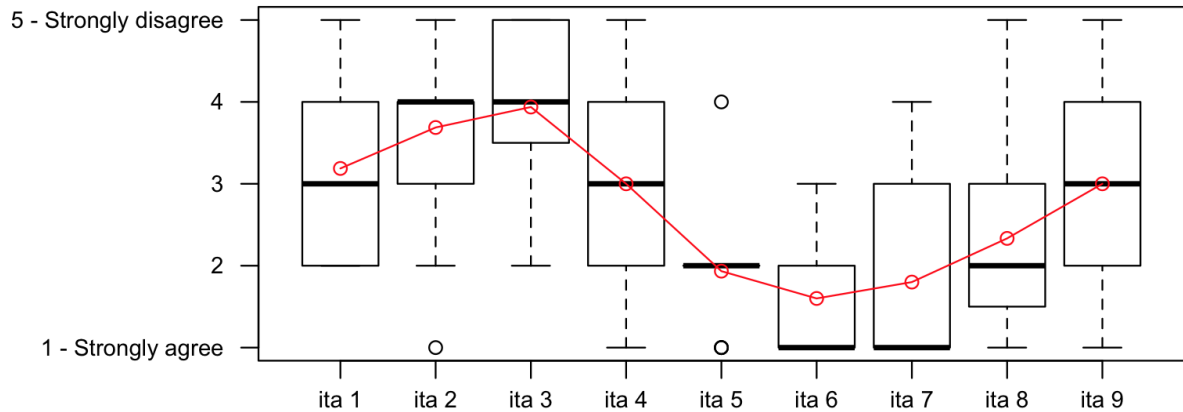


Figure 11. Infrastructure and Technology Acceptance

4.1.7. Interoperability

The following graphs display the answers to the rating question “How important is interoperability to your customers?” (see Table 16, Figure 12, and Table 17).

Participants agree that interoperability is important for their customer organisations. Vendor lock-in is indicated as a highly relevant issue. At the same time, integration costs for other software systems are seen as being excessive, while an ecosystem of compatible products is not recognised by the participants.

A lack of AR-accessible contents is stated while participants don’t agree, that content re-use from the web is simple. With respect to the authoring of content, no clear trend with respect to reuse or the use of specific AR authoring tools can be seen.

In terms of content formats, a large variety of media formats, file types and content types is listed, including graphical formats, learning object standards, and content descriptors. No existing or supported APIs have been mentioned by participants.

Table 16. Interoperability: items

Variable	Description
in1	Interoperability is important to our customer organizations.
in2	Our customers are worried about vendor lock-in.
in3	Integration costs with other software systems are excessive.
in4	There is an ecosystem of compatible products.
in5	There is a lack of AR-accessible content.
in6	Content re-use from the web / other media is simple.
in7	We author content only once and then export to the different AR browsers.
in8	We author content in situ using an AR app.

AR/WT Interoperability

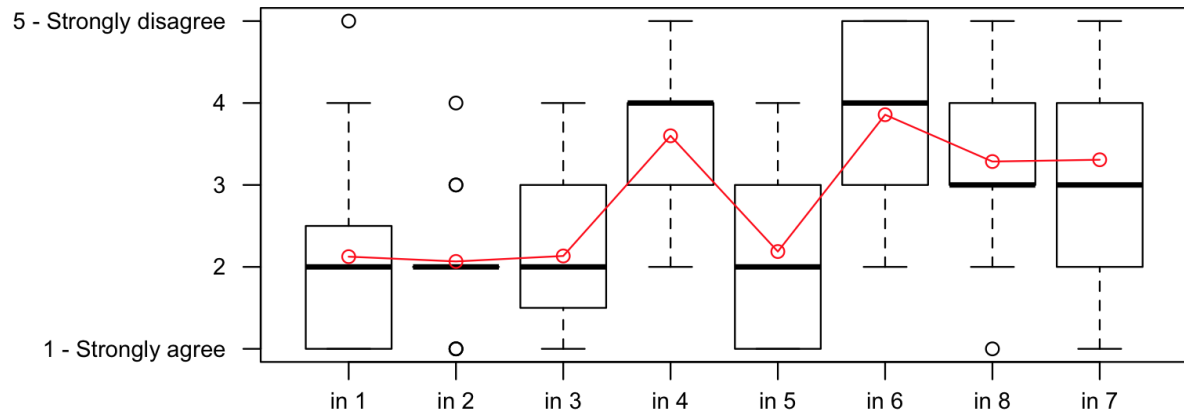


Figure 12. Interoperability

Table 17. Interoperability/Formats: additional answers

What content formats do you support (learning objects, technical documentation etc.)? (Open Text)

- FBX, CSV.
- We support a variety of content formats including audio, video, images, 3D models, VR panoramas, text. Regarding the supported 3D formats we work with JT, IGES, OBJ, FBX, IVE and many others.
- Learning objects.
- Location-based information and resources.
- Technical specs, API docs, concrete examples, interactive examples would be perfect!

4.1.8. Price value, Regulations and conformance

While participants rather think that AR/WT systems are slightly overpriced (Figure 13, pvr1), they still assign a good price value for AR/WT systems for their customers (Figure 13, pvr2).

Participants don't see the development of AR/WT to be affected strongly by regulations. However, privacy regulations, information security regulations, work safety regulations, equipment specification regulations are mentioned as relevant regulations (Figure 13, pvr3).

Table 18. Price value, regulations, conformance: items

Variable	Description
pvr1	AR/WT systems are reasonably priced according to our customers.
pvr2	At the current price, AR/WT systems provide a good value for our customers.
pvr3	There are regulations that clearly affect the AR/WT development.

Price value, Regulations and conformance

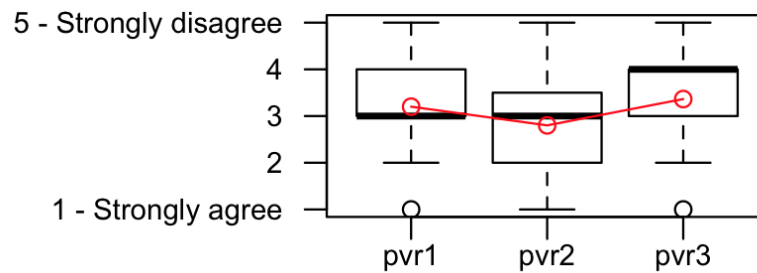


Figure 13. Price value, regulations and conformance

4.1.9. Personal Background

Most of the participants have at least some experience with AR/WT, however the use of AR/WT as part of daily routine is sparse (Figure 14 a). The majority of our participants have a research or development background with a few participants being trainers or content developers. Some participants added management roles, innovation leader, or educational specialist roles to the list (Figure 14 b).

Regarding devices, then clearly smartphones and tablets currently dominate by being used permanently or often, while smartglasses, smartwatches, and fitness trackers are not used at all by most of the participants. It is, however, noteworthy that a minority of participants indicated that they use smartglasses and smartwatches permanently (Table 19, Figure 15).

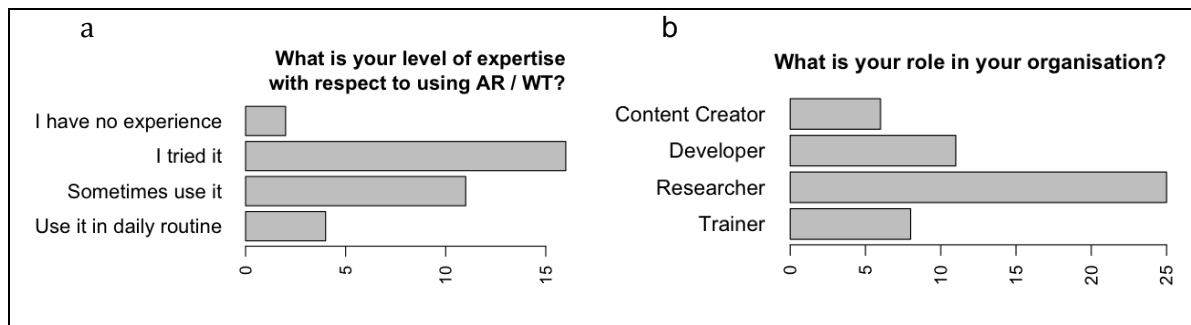


Figure 14. Role and Expertise

Table 19. Device usage frequency: items

Variable	Description
du1	Smartphone
du2	Tablet
du3	Smart Glasses (e.g. Google Glass, Epson Moverio)
du4	Smart Watch
du5	Fitness Tracker

Device Usage

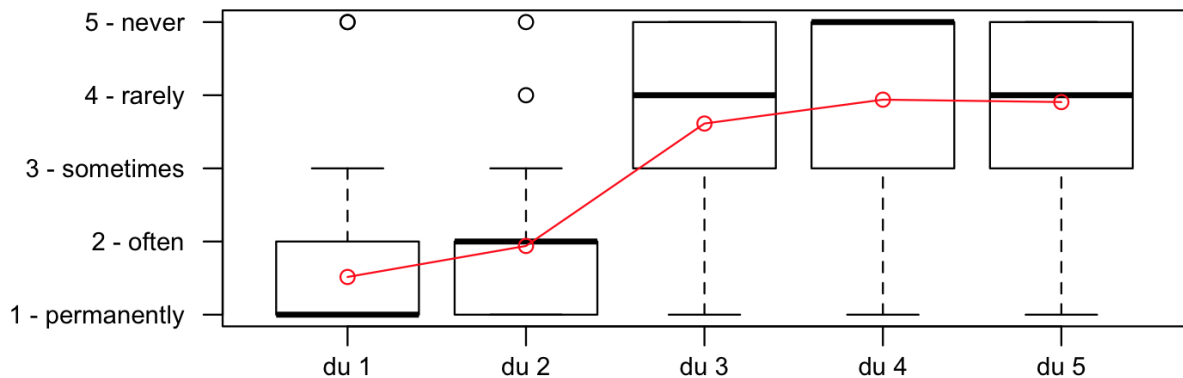


Figure 15. Device usage frequency

4.1.10. Your organisation

The majority of participants comes from large organisations with more than 500 (or even more than 5000) employees (Figure 16 a). In terms of business fields, universities and research organisations dominate, followed by training providers and AR/WT software developers. AR/WT hardware developers only marginally participated (Figure 16 b). Participants added ICT, digital production, RDI organisation, aircraft maintenance, media industry, and helicopter OEM to the list.

Participants mainly see research & development as driver for AR/WT in their organisation, followed by management. To a lesser extent, production and maintenance are seen as drivers (Figure 16 c). Innovation labs and individual faculties are added to the list. With respect to decision taking about AR/WT the situation is dominated by management decisions followed by research & development. HR, customers, and maintenance currently play a minor role (Figure 16 d). Innovation labs and academic department are added to the list

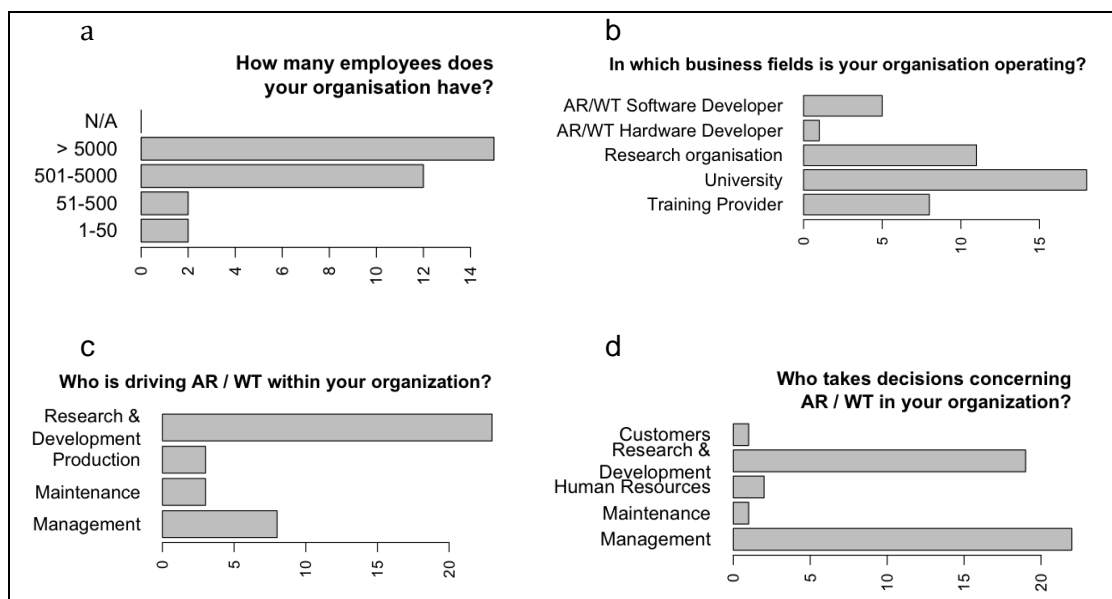


Figure 16. Your organisation

4.1.11. The WEKIT Community

With respect to further contacts, participants are mainly interested in AR/WT solution developers, followed by AR/WT training developers and industrial training providers (Figure 17 a). Generally, the participants are currently more interested in research outcomes for initial trials and in pilot applications than in applicable solutions (Figure 17 a).

Participants listed some components which they can contribute, including virtual world platforms (realXtend), mobile learning platform (ARLearn), AR platforms and developments, and LMS integration (Table 20).

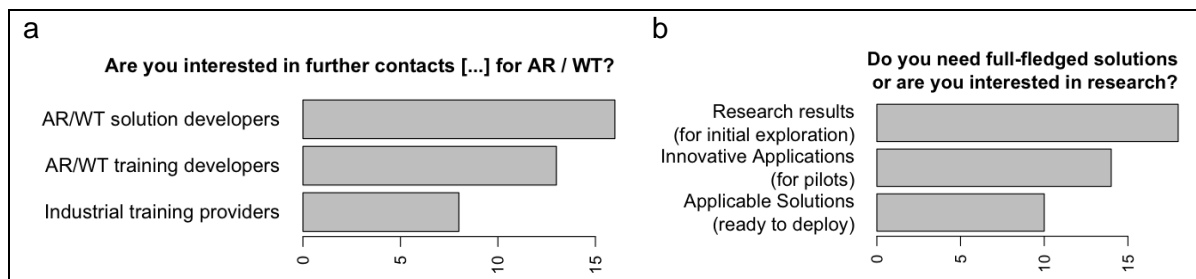


Figure 17. Interest in the WEKIT community

Table 20. Contributions to the WEKIT community

Which components could you contribute to the WEKIT.one Open Source Technology Platform? (Open Text)

- ARLearn
- In Oulu, Finland, we have been developing an OS platform for virtual worlds called realXtend. I'm sure this platform could be linked to WEKIT.
- Not sure. We would definitely love to learn more about the project and see if we can somehow help further develop it.
- AR developments and platforms.
- LMS Integration.

4.2. Quantitative and Qualitative Data Survey 2: Current level of Technology Acceptance

The final resulting questionnaire now allows us administer another survey with participants from the pilot companies, which gives us a 'baseline' of what drives technology acceptance, use, and all the other success factors.

We've run the questionnaire amongst the three pilot partners, with the aim to draw an equal share of participants for each pilot area WEKIT is looking at (about 10 each). Additional people across the consortium contributed.

Most of our participants are male and from the age group of 25-44, with only a few being younger or older. Respondents come mainly from the space industry and the educational field, with additional participants from transportation, in R&D, in manufacturing, and in health. Participants added

maintenance, media, IT consulting, and telecommunication service provider to the list of industries offered. Within these organisations participants are mainly researchers or end-users, with some participants being managers, developers, or trainers.

The respondents generally look forward to using AR/WT (ATU4) or are neutral about it and plan to use AR/WT in their daily life (BI2). They are rather neutral about learnability of AR/WT for being similar to existing technologies (CSE4), but agree that their interaction with AR/WT is generally clear and understandable (EE2).

Participants do not necessarily have the resources available (FC1) to use AR/WT (some do, some don't), but the majority likes working with AR/WT (HM2b) without feeling addicted to it (HT2). They don't see AR/WT as prestigious tools (IMG1) but rather a tool for forerunners (IMG4).

Interoperability is seen as a highly relevant issue (IOP1) and participants are slightly worried about vendor lock-ins (IOP2). They fear high integration costs for AR/WT solutions (IOP3).

Participants are rather neutral about privacy and security aspects, i.e. the use of AR/WT for informing others about current activity or location (IS6). Also, they are neutral about the learning curve needed to adopt AR/WT (LRN1).

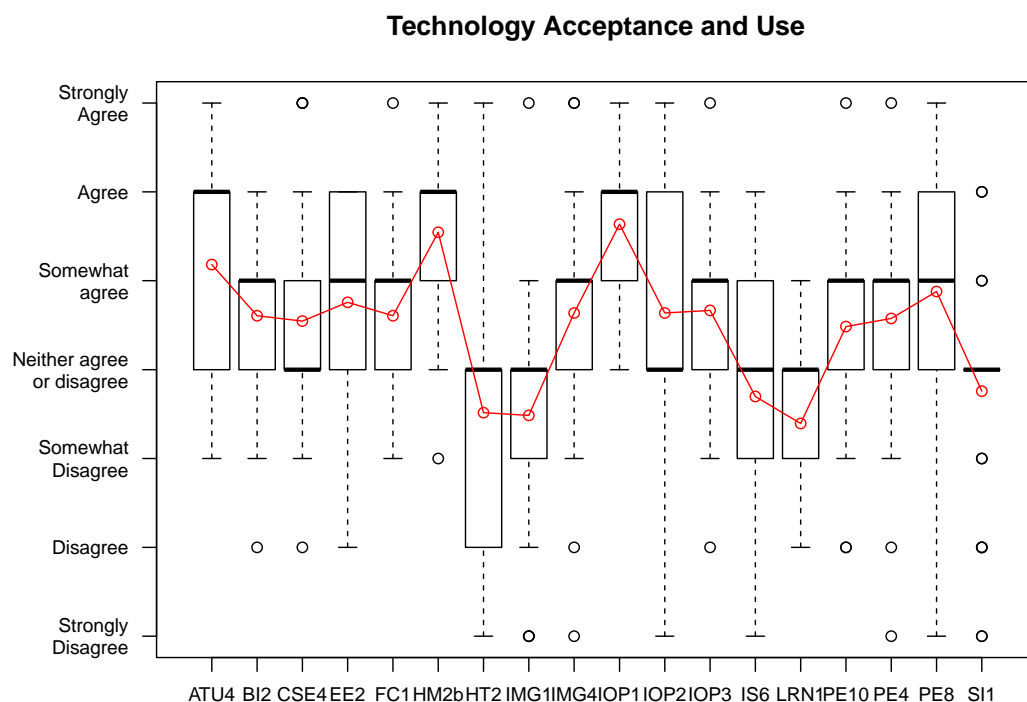


Figure 18. Variables of the technology acceptance model.

With respect to performance expectancy, participants are slightly inclined to believe in an increase of productivity (PE4), an increase of precision (PE8), and the advantage of feedback on task completion (PE10).

Participants are rather neutral about social influence of other people on the use of AR/WT (SI1).

The majority of participants have no experience in the use (UF1) of AR/WT (never: n=14), some use AR/WT rarely (once/month: n=7; once/two weeks: n=6). Only a few people use AR/WT on a regular basis (daily: n=1; several times a week: n=5).

Testing reliability of the developed questionnaire with a split half reliability test (Diekmann, 2002, p.253). This mean calculating the correlation between the sum scores of odd-column items versus the sum scores of even-column items, resulting in a Pearson's r value of 0.77.

Since 'limiting' the number of items for the halves to half the full set, the underestimation can be corrected with the Spearman and Brown formula: $r_s = 2 * r_{s1,s2} / (1 + r_{s1,s2})$. This results in r_s of 0.87, which is above the recommended value of 0.80 (Diekmann, 2002, p.253). The standardised Cronbach's alpha is 0.86 (same with the raw alpha).

5. Evaluation of interview data

In this chapter the results from company interviews will be presented. Representatives from altogether three (3) companies were interviewed at this stage of the project. The domains or business areas included space, maintenance business (focusing especially on machine building) and robots in manufacturing. Furthermore, the companies represented both AR end-users (2) and AR developers (1).

The results from the interviews will be presented case-by-case so that each company is a separate case.

5.1. Case company 1: Space domain

Table 21. Case company 1: information

Item	Description
<i>Number of employees</i>	80
<i>Field of business & innovation focus</i>	Space <ul style="list-style-type: none"> ♦ AR end-user ♦ Engineering and logistic services for space (support activities) ♦ Research activities
<i>Interviewees (total: 5)</i>	<i>Technical Director</i>
	<i>Technical Operation Responsible</i>
	<i>Developer</i>
	<i>Trainer</i>
	<i>Trainer</i>

5.1.1. CURRENT USE OF AUGMENTED REALITY

Can you please describe, how is AR used in this organisation?

The company is the prime contractor of ESA for training, logistics and operation support services. In terms of normal activities, AR is not used much in the company. However, the company is ready and willing to replace current activities and tools with new practices and products. They are very interested in AR for astronaut training and mission support. For example decision-making is very important for astronauts during mission, and AR can support that.

AR is not very much used in astronaut training. The technology is not mature yet. People often think that in space the most recent hardware and software are used – that is not true. The tools have to be very consolidated because problems have to be avoided. AR is not mature enough yet.

The company has been involved in AR development projects. The created demonstration systems with mock-ups and scenarios have been tested for feasibility. It is thus understood what can be done with AR. Some potential and interesting future plans with AR could include:

- AR for evaluation of risks related to humans. For example, if the astronaut is tired and possibly making errors because of that. This is also a delicate issue: Do the astronauts want to be under evaluation / surveillance all the time?
- Comparing human behaviour during mission: In the beginning of the mission compared with later phases of mission.

5.1.2. EDUCATIONAL NEEDS

In the future for the planetary exploration, the space mission will last for 3 years with little possibilities for support. The astronauts have to be more autonomous because of that reason. It's not possible to be ready completely for 3 year mission; the astronauts have to learn things during the mission, with on-the-job learning. Other thing is that astronauts cannot be followed real time. The time lag will be 6-20 minutes (one direction). The astronauts have to make decisions without guidance from the ground. They have to be more independent when travelling to for example Mars.

International partners (ESA) make the final decision on use of AR in training. The company is promoting the use of AR. ESA is looking for new ways of training. Currently, the time spent on maintenance training on ground is very long. Most of the trained activities will never be performed in real life, because they do not occur. The aim is to shorten the ground training and teach only the most important and necessary things. Decreasing the ground training time is a key target.

The systems become more and more complex. Thus, it's not feasible to have very extensive training of everything. Trainers have to prioritize. Additional training needs to be created for things that are not prioritized.

Virtual reality is very good for giving an overview of the task before the actual task performance, but in the actual situation in real life AR is better. The astronauts want to see the real object (hardware) with additional information. The picture of the hardware is not enough.

For an astronaut, it is important to have visual / virtual telemetric data available, so that they understand how the component is working. For experienced astronaut telemetric data is enough, the do not need pictures of scissors to show which wire should be cut, for example. The AR system should thus give different type of guidance and instructions:

- For the inexperienced learner, all the actions should be explained with limited telemetric data.
- For the expert, more telemetric data available (not too much visualization), and lower level simple actions hidden.

It is important that the AR system should be able to follow changes and adapt: it should be able to record situations and present new information next time.

5.1.3. Comments on suggested main goals of training:

Taking the right decisions in complex situations

- **Important.** Actual problem case: There was a mistake in the instruction, thus the astronaut needed real time guidance to solve the problem from the expert.

Performing tasks at highest possible speed

- The time needed for performing an activity is calculated. Crew time is very expensive, thus it would be good if the time needed for performing tasks could be reduced. From astronaut viewpoint, reducing time especially in emergency and life-threatening situations would be important. Time is a critical resource in space, thus doing things quickly, well and safely is hoped for.

5.1.4. AR TECHNOLOGY READINESS

The technology is not mature yet. However, AR is already part of company's research. It's already outlined and part of the future plans. There is always uncertainty related to technology. However, there are long term plans related to for example Mars mission. It is going to take maybe decades to go to Mars. So there is time to develop the technology.

5.1.5. What would be the greatest application for AR – the killer application?

- ♦ AR may be useful for several applications. It would be good to shorten processes and to facilitate something. Today the main problem is to protect astronauts from radiation, but it has probably not much to do with AR.
- ♦ Application that reduces the ground training time, which is now 18 – 24 months. It would save a lot of costs. From astronaut's perspective, the trainees have to travel a lot to get training. If they could stay a longer period in the same location, it would be better from the viewpoint of their private life, such as family life. Also training tools that can be used during the mission would be good, because astronauts' motivation will decrease if they don't have anything to do. Tools that support autonomous self-learning would be good.
- ♦ The tool that enables easily and quickly the modifying and updating of the procedures, since the procedures often change until the last minute. The big problem is to assemble the data to be displayed. The final visualization of the AR tool is not that important, preparing the data is more important.
- ♦ The system should be easy and natural to use. The system should not interfere the normal work. For example, not all the astronauts like the glasses.

5.1.6. TECHNOLOGY ACCEPTANCE – PERFORMANCE EXPECTANCY

The astronaut trainees would like AR technology very much. Astronauts are usually very interested in new solutions and applications and would like to have more opportunities to try and evaluate them. It is also expected that they perform experiences; it is part of their work. However, the AR tool has to solve the real and current problems to be successful – there has to be the clear link between the need and the tool.

Astronauts are proud of their work and knowledge, they don't want be trained like monkeys. Thus it is important to provide them with information they personally need for completing the task. The astronauts should have the easy access to information, but they should not be forced to receive anything. Often guidelines and hints are enough for them, not step-by-step instructions.

There are different types of personalities among astronauts: Some of them follow the procedures and instructions (checklists) more carefully and precisely than others. This has to be considered in training: It is important to provide briefing and overview of the whole task before starting the performance. Providing only detailed steps on the task might confuse and irritate some learners. As a summary, the level of expertise and type of personality are affecting the use of AR solutions, and a successful solution should recognise these elements.

Problems which may restrict the use of AR:

- ◆ Maturity of technology. It could be mature enough for demonstration to show the potential.
- ◆ Individual vs. collective data. For example with AR glasses it's not easy to share important information with other team members.
- ◆ Medical issues: A person can't live 24 hours with AR.
- ◆ Experience on AR (virtual) helmet: It was isolating users from the rest of the environment. Their view was limited by the helmet.

5.1.7. Regulations

Regulations are mainly related to the functionality and reliability of tools and connectivity. The tools have to be very solid.

The astronauts are using tablets (iPads) in space. It has been a good tool to use. The tablet is configured in a very consolidated way. It should be approved by NASA and Russians (Russian Space Agency, RSC Energia). Any application that is uploaded to the tablet should go through the approval process controlled by certain board. This process will take at least 6 months.

5.1.8. Pricing and investment

It's case by case. Generally the items are not so expensive. Problem is that you never find exactly what you need.

All the agencies are very interested in developing learning solutions for long duration missions and explorations. It is maybe not the question of cost-effectiveness; AR might be the only way to provide sufficient materials for the astronauts.

5.1.9. USE CASE: Maintenance in space

Ideas for use case:

- ◆ In the use case, AR should provide some real added value to the task performance. 30 minutes would be a suitable time for performing the use case demo task.
- ◆ For example, if you have to tighten the screws to certain value based on Newton metre, AR could show the values.
- ◆ AR could be also be related to safety issues and for example show if some item's temperature is too high for touching.
- ◆ Accessibility to different places / locations is also important, especially in zero G with no gravity. VR/AR can give the trainee the impression what the astronaut will see in Zero G. The "X-ray" view that AR can provide is also useful in places with many cables and connectors.
- ◆ It is important to define how to collect the data and how to merge it, to create links between the information.
- ◆ Collecting and providing tacit knowledge could also be important.

5.2. Case company 2: Maintenance

Table 22. Case company 2: information

Item	Description
<i>Number of employees</i>	8 (start-up)
<i>Field of business & innovation focus</i>	Maintenance business <ul style="list-style-type: none"> ◆ AR developer ◆ Main customer area: Machine building ◆ Remote support and maintenance solutions (based on AR principles) ◆ Target of development: Enhancing technical communication between technical people
<i>Interviewees (total: 2)</i>	<i>CEO (Chief Executive Officer)</i>
	<i>CTO (Chief Technology Officer)</i>

5.2.1. CURRENT USE OF AUGMENTED REALITY

Can you please describe, how is AR used in your customer organisations?

As an AR developer, the company's background is in space industry. Original problem to be solved was how to remotely support astronauts in their work. Later on it became evident, that there was a need for remote support in other areas as well, especially in machine building area.

All of the company's customers in machine building are investing on in-house AR. The big companies have all used AR already, and all the customers have strategies which include AR.

Company's customer use cases are related to following areas and issues:

- Maintenance
- Training
 - Sharing expert knowledge with novices; on-the-job training
- Modernization
 - upgrades, retrofits
- Commissioning
- Installation
- Quality assurance
 - Many companies hope that there would be a way to record and store the customer's problem case.
- Warranty time support
 - Quality assurance and warranty issues: Companies want to help their customers, but there is not enough staff / resources for visiting the customers. With remote support system this can be done more easily.

The situation today is that main tools for communication and customer support are phone and email. Sometimes applications like WhatsApp are used as well. These are not sufficient in many cases, and a lot of time and effort are wasted due to poor communication. The company's product provides live

video streaming, voice chat and real time remote pointing for annotations. The device the company is using for their solution is mobile phone, since almost everyone is already using the device.

5.2.2. EDUCATIONAL NEEDS

The training (and educational) needs are very much about the problem between the expert and the new worker, or between the good and poor performing worker. The knowledge gap is the problem. Any tool that can help novices to be ready to go to the field alone faster is needed.

The needs are also related to:

- ◆ Introduction of new products
- ◆ Manuals: Learners have manuals, but many additional things go beyond the manual
- ◆ Updating instructions quickly

5.2.3. Comments on suggested main goals of training:

- Taking the right decisions in complex situations
 - **Most important.** Making decisions on next steps for example. In what order procedure phases / actions should be done. This is very natural and suitable for AR.
- Performing tasks with highest possible precision
 - Can be important in modernization for example.
- Performing tasks at highest possible speed
 - AR is not technologically ready, so it might decrease the speed.
- Reducing error rates
 - For routine work (checklist) could be suitable. Related to precisions.

5.2.4. AR TECHNOLOGY READINESS

There are not suitable proper tools especially made for technicians. The current tools are not built from technicians' point of view, thus they are not interested in using current tools and apps (WhatsApp, Skype etc.).

The AR technology is not ready yet. Usability is one problem, as well as reliability. Lighting, dirt and all the variation in context causes problems. Technology readiness level is probably TRL6 for AR systems, not higher.

5.2.5. What would be the greatest application for AR – the killer application?

AR tool for remote support (company's own product). It would be a very simple tool with well-functioning tracking.

5.2.6. TECHNOLOGY ACCEPTANCE – PERFORMANCE EXPECTANCY

A lot of people among company's customers have big dreams on AR, but many have already "burnt their fingers". The dream is not delivered yet, but they still want to dream. The promise of AR is so huge.

The company tries to work on grass root level, with actual field technicians, to make the system work properly. From field technicians' perspective, their working has to become easier. AR has to be helpful in their work. And the work should become more fun. Engineers often think the system has to be useful, but it also has to be fun, sexy and cool. The managers are mainly interested in time saving, travel costs (etc.).

One potential customer didn't want to use the company's remote support system because it would have indicated that the customer has a problem. They didn't want to show that they have the problem so they didn't want the system.

If a person is using AR in order to help others, and become the "Champion Expert" in the company, then it is a good thing from acceptance viewpoint.

5.2.7. Pricing and investment

If the tool really helps the customer (end user), money is usually not the problem. Too cheap can be a problem too. However, the expectation is that the investment should give 10 times back.

It's very difficult to say generally who makes the decisions related to the use of AR. If the investment is really big, then it's usually CEO. When selling the AR, first you have to find people who know and understand the technology and believe in it, and then you have to find the actual decision makers. The decision makers are influenced by the first category of people. It's always navigation inside the company, looking for the right persons.

5.2.8. USE CASE: Maintenance in space

Even if the use of AR might improve precision and reduce errors, AR might still slow down the work. If the speed decreases due to usability and technology readiness issues, the users might not want to use the system.

Most important to think when further developing the use case: What are the things that astronaut is missing? What went wrong - what is hard for astronauts to remember?

Other ideas:

- ◆ Reduction of cognitive load with AR can be a target.
- ◆ AR is good for training of cases that are too expensive to organise in reality.
- ◆ AR is good for refreshment training as well.

5.3. Case company 3: Robotics and maintenance

Table 23. Case company 3: information

Item	Description
<i>Number of employees</i>	10
<i>Field of business & innovation focus</i>	Robots in manufacturing <ul style="list-style-type: none"> ◆ AR end-user ◆ Developer of hardware and software for industrial robots ◆ Maintenance of robot installations and automated production lines
<i>Interviewees (total: 1 full interview + 1 short interview to confirm the major points)</i>	<i>Full interview: Research Engineer</i>
	<i>Short interview: Managing director and Project Coordinator</i>

5.3.1. CURRENT USE OF AUGMENTED REALITY

Can you please describe, how is AR used in this organisation?

Currently the company does not provide AR solutions for customers. It is still in research phase. And I am the only person in the company who works in this exact area. We are trying devices, talking to companies and looking at the libraries and development kits for the new devices, cooperating with universities working in this field involving them into industry projects. We have experience with simulations and VR, mostly in the context of setting up robots.

The company has an interest sensor technology and using AR devices to find out how to improve communication between machines and humans, to include more senses. The company is looking at what industry processes need this, how to communicate the information from industrial processes to humans.

The company is also interested in improving maintenance and resolving problems using AR instead of traveling to the location (what is normally done)

5.3.2. EDUCATIONAL NEEDS

We use standard methods for training. We implement applications constantly discussing with the customer, finding out their needs. We provide training for customers in our offices and in the location of customers - there it is learning by doing. They have documentation and we show how to use it.

5.3.3. AR TECHNOLOGY READINESS

The technology is not mature yet. Microsoft hololens is something we would expect - small glasses with a good field of view, but not the large helmets. The first step we see is to develop the technology for good mobile cameras/sensors and then adapt to the users.

The company has a goal to create user-friendly applications and practical solutions and as effective support as possible. Communication with humans is an important component.

We have to communicate local knowledge and local experience to our expert side remotely. So it is in the air that AR is coming into it. However, it is not easy to introduce. Many functions need to be developed. The hardware is not as good as we expect: bulky and not natural.

5.3.4. What would be the greatest application for AR – the killer application?

Hardware: From the developer point of view, we need the view and the view gesture recognition and natural interaction. “Minority report” - metaphor.

Application: plug and play, define functionality, easy to customize to our cases - this would be a wow.

What would this killer app solve?

It would be cool and easy to work at the customer workplace, faster.

Will regulations and standards create barriers?

After a while, the industry standards will be out. The standards and regulations will follow easier implementations and compatibility. The AR devices will also have to have these. And installing cameras will create a need to care about personal rights. It even can be counterproductive.

5.3.5. TECHNOLOGY ACCEPTANCE – PERFORMANCE EXPECTANCY

What would be the level of technology that the workers accept it?

- Compactness (no bulky helmets, for example, in some places workers have to wear safety glasses, but is they do not need them, they do not wear them)
- Embedded into the environment
 - For example, the AR glasses should work together with the safety glasses
 - For example, cameras and AR displays built into the motorbike helmets (which you would need anyway)
 - But not force the worker to wear an additional, especially large, device.
- The growing up generation will more likely to accept additional devices.

What would be an example of bad experience?

When you have more difficulties than advantages:

- When you need information urgently, but your gesture is not recognized, and you would get it manually faster
- When you get too much information which is disturbing
- When the voice recognition does not work (voice-activated elevator)

Would you be interested in joining the WEKIT community and/or using the WEKIT.one platform?

It reminds me the Robot Operating System (ROS). We are currently working with this community. It has many companies behind it. They also have a framework, server, communication, etc. You can connect devices, build network, and communicate - industry 4.0. It is very easy, plug and play. We try to integrate industrial devices into it. So, if the WEKIT framework connects to ROS, we would be much more likely to use it too. Other similar platforms to connect to: RT middleware and matlab.

5.3.6. Pricing and investment

What would make you decide to invest into an AR solution from the user/customer perspective?

- How easy we can integrate them into our current devices. It is not material and not the hardware. In Norway, it is not the point how much the hardware cost, but how much time do you need to develop technology (applications) for it to use it. If a device cost 100 or 500 euro it does not matter comparing to the price of 10 hours of development or a week. If we want to use AR/WT for training,
 - the first thing to do is to check if the technology is suitable for our current context, and
 - second - how much to spend to develop training materials for it.
 - Third - how quickly we can learn how to develop training material for it.
- The customer wants as cheap solution as possible (not always the cheapest, of course). We have to say that the price is reasonable and it saves money.

Does the current price level of AR/WT match the level of technology?

We are waiting for the right technology. It is more important than the price.

5.3.7. USE CASE:

The most interesting use cases for us are:

- Remote assistance
- Training employees
- Enhancing the environment with useful information, checking the visual cues. Information where it is needed.

6. Conclusions: Affordances required

Generally, our data indicates that the interest in AR/WT solutions is high and expectations towards the problems AR/WT solutions will be able to solve are numerous (e.g. acceleration of electronic work instructions, lowering costs for task performance, faster task completion, reduction of errors, increase of precision, integration with existing solutions, and increase of workplace appeal to younger employees).

On the other hand, practical applications of AR/WT are currently sparse, the integration of AR/WT in educational processes is on a marginal level and hands-on experiences with AR/WT technologies are quite limited. Also, relevant practical experiences with AR/WT in our participants base are rare. Among the examined case companies, the expectations towards AR/WT are still high, even though some of them report some bad experiences on how their customers have “burnt their fingers”. The promise of AR/WT is not delivered yet. The challenge in the future is to provide real added value AR/WT solutions.

However, our survey participants and interviewees are looking forward to see AR/WT becoming part of their daily life, their task routine, and their educational processes. The general acceptance of AR/WT technology seems to be on a quite high level based on the surveys and interviews.

From surveys and interviews, we extracted a number of relevant insights from the viewpoints of industry, users and technology, based on which applications for AR/WT should be constructed. These insights are presented and discussed in the following subsections.

6.1. Industry Needs

Insight I1: Generally, AR/WT solutions are expected to shorten processes and to facilitate activities.

From training viewpoint, shortening the basic training period that is needed before the novice worker can start the actual work is an obvious need. AR/WT solutions need to support on-site guidance and learning: They should facilitate both real time remote support provided by a real person, and guidance in situations where real-time human-support is not possible. Especially in space domain, the goal is to shift from long and comprehensive ground training periods to more situational, self-directed autonomous learning during space mission. Organising extensive training of everything before the mission is not feasible in the future.

Insight I2: In order to improve task performance, AR/WT is expected to facilitate faster task completion, reduction of errors, increase of precision and decision making.

For example, time is a critical and expensive resource in space: Solutions that speed up actions are desirable. In case of increasing performance speed in task performance it should be noted, that if the AR/WT technology is not mature enough, it easily reduces the performance speed and thus quickly becomes undesirable for the worker.

AR is also seen as a suitable technology to support decision making, such as making decisions on next steps and in what order procedure phases / actions should be done. This was emphasised in case company interviews and seen as a natural task for AR/WT.

Insight I3: The appropriate technology is more important than price.

While survey participants rather think that AR/WT systems are slightly overpriced, they still assign a good price value for AR/WT systems for their customers. If the AR/WR tool really helps the customer (end user), pricing is usually not the main problem. In space domain, AR/WT might be the only way to provide sufficient learning materials in the future. However, the expectation is that the investment should give a substantial amount back. Furthermore, an important issue is how AR/WR can be integrated to existing systems and devices.

6.2. User Needs

Insight U1: Increasing market potential, but pioneers need to be convinced with strong business case.

We expect, that AR/WT solutions in education and beyond represent a growing field with an increasing market potential. However, vendors of AR/WT solutions are operating in a pioneer-based market and need to be able to identify, address, and convince forerunners. It is likewise crucial, that

solution providers are able to demonstrate the added value in terms of problems solved for AR/WT solutions. Also, educational AR/WT solutions need to integrate with daily life support application cases in order to gain their full potential.

The current educational situation is still largely dominated by traditional educational processes with technological support in the form of learning management systems and e-learning contents. Plans to invest in educational AR/WT solutions, however, indicate a growing relevance of this segment. Clear content strategies for AR/WT can not yet be identified.

Participants are rather positive about the application potential in AR/WT as they indicate relevant applications and additionally list a large number of potential applications and relevant application cases. Also participants assume a high interest in their customer base. Additionally, participants look forward to use AR/WT in their daily life.

In many cases, application cases mentioned by participants go beyond educational activities and include support in daily life situations such as task support, context information, awareness, and communication.

Insight U2: Market push: In order to get AR/WT solutions into productive use, R&D initiatives need to clearly motivate the benefit and added value offered. Management initiatives also need to strengthen acceptance and to address barriers.

Currently, AR/WT developments are mainly driven by R&D initiatives within organisations but also by management initiatives. Productive organisational units such as production and maintenance currently play a minor role.

Also, participants are mainly interested in research outcomes and innovative applications currently, which indicates, that solutions are not yet on the required level of maturity for productive use.

Insight U3: We successfully raised interest for the WEKIT community and could show, that WEKIT is addressing relevant topics. It is now necessary, to follow up the contacts and complement these activities with further community building efforts.

About half of the participants are interested in further contacts regarding the WEKIT project and its outcomes. Also some participants indicate, that they would be able to contribute to the WEKIT project with technologies or conceptual inputs.

Insight U4: The whole process of guiding and instructing the learner should be rethought.

The use of AR will change the process, including the learning method. From the user (learner) perspective, this means more autonomous learning without predetermined training periods. This might require further research of training and work processes, tasks and contexts. Providing the content will be especially challenging: In autonomous on-site learning situations the AR system should be able to follow changes and adapt: it should be able to record situations and present new suitable information next time.

Insight U5: The AR system could be more complex and less mature from user experience viewpoint when capturing the expert's performance.

In the actual learning situation when re-enacting the experience for the learner, the system should be less complex, easy and fun to use.

Insight U6: Application design in the grass-root level is important; the system must be desirable from the viewpoint of the real end-user.

The data indicated that the system needs to be “fun and cool”; good usability is not enough. The whole user experience should be tempting. The usability and reliability of terminal devices is currently a barrier. When choosing the device(s), the actual users' experience and preferences should be examined.

Insight U7: The starting point should be that AR system gives more general framework and guidelines for task performance.

Lower level action guidance and step-by-step instructions should be displayed only when needed, based on the user's level of expertise and personal preferences. Providing briefing and orientation before the actual performance is important.

6.3. Technology Needs

Insight T1: The AR system should be able to show and visualize things that cannot be shown in normal training situation.

These would include for example telemetric data, “X-ray” view and view in exceptional conditions such as in zero gravity (space domain). Generally, the AR/WR solution should give “added value” to the user during task performance, otherwise the solution easily becomes undesirable.

Insight T2: The display and visualization of learning content should adapt to the both level of expertise and personality (e.g. personal preferences, learning styles) of the learner.

Both of these elements are affecting the learning situation and need, and a successful solution should adapt to these elements.

Insight T3: The user interface should be adaptable.

Among the barriers to the adoption of AR/WT mentioned, we found lack of standards and integration paths as well as technological limitations and high customisation costs. Also infrastructural issues and security requirements are barriers. In terms of technological readiness, participants see some aspects of AR/WT as being mature, while others are still lacking behind and produce bottlenecks to the widespread use of AR/WT.

Insight T4: We expect that emerging interoperability standards for AR/WT such as ARLEM will be of increasing importance and play a role to change this shortcoming. Vendors of AR/WT solutions need to agree on interoperability standards and content exchange standards in order to provide AR/WT platforms of wide spread acceptance.

While AR/WT is highly interesting for customers, a lot of work needs to be done to raise awareness at customers and convince customers from potential benefits. Generally, participants also rate the price value of AR/WT to be fair. Interoperability is a highly relevant topic for most participants, where currently the support through accepted interoperability standards is missing, which also leads to a lack of re-usable AR-accessible contents. Vendor lock-in, high integration costs and interoperability issues are seen as relevant barriers.

Insight T5: We expect that wearable devices become cheaper and current technological constraints are becoming less of a barrier. However, any AR/WT solution needs to support various platforms in order to be successful, including smartphones, tablets, and smart glasses.

Clearly, smartphones and tablets dominate the field of mobile computing devices today. Smart glasses, smart watches, and other wearable devices are rarely used yet.

SmartGlasses available at the time of project start are considered to be on a low level of technological readiness as they offer too many weaknesses and technological constraints in terms of usability, field of vision, or battery runtime. Recently launched and announced devices and first hands-on experiences with these appear to dramatically improve the quality and usability of smart glasses.

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Appendix A.1 – First questionnaire

Augmented Reality and Wearable Technologies in Training and Education

Augmented reality (AR) and wearable technologies (WT) show huge potential to change the way we educate and train. In the publicly-funded WEKIT project, we explore experience capturing to support observation of a master performing problem-solving tasks and to deliver augmented real-time guidance to trainees.



With this questionnaire, we aim to survey your past experience and future expectations. This is a unique opportunity to provide your insights and opinions as input to the development of a public technology roadmap and its implementation in an open platform.



Before you start with this survey, please watch the introductory video. The full survey questionnaire takes about 15 minutes to complete. *A note on privacy*
We respect your privacy. The information entered here will only be used for research purposes. If personal information is requested, it will only be used to contact you if you indicate your interest. We will not give personal information to third parties.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 687669

There are 57 questions in this survey

Your organisational background. These questions help us to decide on some of the follow-up questions

These questions help us to decide on some of the follow-up questions on the next pages.

[]Does your organisation deliver educational services or do internal HR development?

Please choose **only one** of the following:

Yes

No

[]Are you using educational content within your organisation (self-made, tailored, externally provided)?

Please choose **only one** of the following:

Yes

No

[]Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?

Please choose **only one** of the following:

Yes

No

Education and training in your organisation

This section is relevant to HR professionals only. If you do not belong to that group, you may skip this section.

How about the educational and training situation in your organisation?

[]How many trainers or teachers work in/for your organisation?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '1 [EducationAvailable]' (Does your organisation deliver educational services or do internal HR development?)

Please choose **only one** of the following:

1-10

11-50

51-200

more than 200

[]How many learners do you have in your organisation?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '1 [EducationAvailable]' (Does your organisation deliver educational services or do internal HR development?)

Please choose **only one** of the following:

1-10

11-50

51-500

501-5000

more than 5000

[]How are courses and other educational offers / job trainings organised right now?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '1 [EducationAvailable]' (Does your organisation deliver educational services or do internal HR development?)

Please choose **all** that apply:

Seminars / contact courses

Training on the job

E-learning

Other:

[]Which kind of technical support is provided for training?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '1 [EducationAvailable]' (Does your organisation deliver educational services or do internal HR development?)

Please choose **all** that apply:

Learning Management System / Virtual Learning Environment

E-learning contents

Simulations

augmented reality (AR) solution

wearable technology (WT) solution

Learning games

Other:

[]What are the problems/challenges/bottlenecks in the current training workflow and how could augmented reality and wearable technologies help?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '1 [EducationAvailable]' (Does your organisation deliver educational services or do internal HR development?)

Please write your answer here:

[]Who is responsible for the overall design of the training?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '1 [EducationAvailable]' (Does your organisation deliver educational services or do internal HR development?)

Please choose **all** that apply:

Internal trainers

External trainers

Human Resources

Management

Individual departments

Other:

[]What are your future plans in the development of training?

Please choose **all** that apply:

- Investment in educational technology generally
- Investment in AR and wearables specifically
- Intensify work with external providers
- Investment in more trainers
- No investment
- Other:

Educational Content in your organisation

The following questions ask about content, which is used in your organisation for educational purposes.

[]What kind of educational content do you use?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '2 [ContentAvailable]' (Are you using educational content within your organisation (self-made, tailored, externally provided)?)

Please choose **all** that apply:

- Printouts / Books / Scripts
- E-learning
- Wikis/Blogs
- Simulations
- Learning games
- Mobile learning content
- augmented reality (AR) applications
- applications for wearable technologies (WT)
- Other:

[]Which (learning) standards do you use?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '2 [ContentAvailable]' (Are you using educational content within your organisation (self-made, tailored, externally provided)?)

Please choose **all** that apply:

- SCORM
- AICC
- IMS LD
- IEEE ARLEM
- IEEE LOM
- Other:

[]Who is developing content?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '2 [ContentAvailable]' (Are you using educational content within your organisation (self-made, tailored, externally provided)?)

Please choose **all** that apply:

Human Resources
Trainers
In house experts
External service providers
Ready made content
Other:

[]

Which learning objectives are you targeting?

Think of e.g.: practical skills, theoretical concepts, procedural knowledge, knowledge transfer.

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '2 [ContentAvailable]' (Are you using educational content within your organisation (self-made, tailored, externally provided)?)

Please write your answer here:

AR in Education

Here, we are specifically interested in your opinion on augmented reality and their use in your organisation.

[]

Drivers to adoption: What do you think would justify the investment necessary to put in place Augmented Reality systems in your organisation?

Please rate from 1 - highly relevant to 5 - not relevant

Please choose the appropriate response for each item:

	1	2	3	4	5
Accelerates introduction of electronic work instructions.					
Lowers cost of performing the tasks.					
Serves faster task completion.					
Lowers need for training on new tasks.					
Immediately knows when the task (test) is finished.					
Increases compliance.					
Reduces error.					
Increases precision.					

Integrates well with other systems already in
use.

Has approval of management and co-workers.

Increases appeal of our workplace to younger
employees

[[Can you think of additional drivers? If so, please list them here!

Please write your answer here:

[[

**Barriers to adoption: What would prevent you from using Augmented Reality (AR) /
Wearable Technologies (WT) in your organisation?**

Please rate from 1 - highly relevant barrier to 5 - not a barrier

Please choose the appropriate response for each item:

	1	2	3	4	5
Can't hold the tablet while performing tasks (I need to use hands)					
Learning curve is too high compared with the value it would offer					
High cost of customization of systems					
Lack of standard, off-the-shelf solutions					
Negative past experiences with similar technologies					
Lack of experience with similar technologies					
Lack of IT support for this technology					
Insufficient precision and/or resolution of the technology					
Not integrated with other systems already in use					
It's not currently provided by the manufacturer of equipment					
Devices and software not certified or compliant with workplace policy or regulation					
Concerns in using AR/WT with respect to content					

Concerns in using AR/WT with respect to
target groups

[]Can you think of additional barriers? If so, please list them here!

Please write your answer here:

AR Application Perspective

Here, we would like to ask you about existing and potential applications of AR

[]Do you already use augmented reality / wearable apps?

Please choose **only one** of the following:

- Not yet
- Concrete plans available
- Experimental use
- Productive use

[]If other than „not yet“: what kind of applications do you (plan to) use?

Please choose **all** that apply:

- Educational
- Maintenance
- Production support
- Research
- Customer experience
- Marketing
- Other:

[]Which potential application areas (domains) can you foresee for the future?

Please write your answer here:

[]Do you think your clients will be interested in augmented reality (AR) / wearable technologies (WT) in education?

Please choose **only one** of the following:

- Yes, they already expressed interest
- Yes, I assume a high interest
- Maybe, but we don't know yet
- No, I don't think so

[]Do you already have requests/clients interested/asking about augmented reality (AR) / wearable technologies (WT) training?

Please choose **only one** of the following:

- None yet
- Rarely

Some

Many

Do you plan to invest in augmented reality (AR) / wearable technologies (WT) in the coming 3-5 years?

Please choose **only one** of the following:

Yes

No

☐

Affordance Map: which of the following are relevant application cases for augmented reality (AR) / wearable technologies (WT)?

Please rate from 1 - highly relevant to 5 - not relevant

Please choose the appropriate response for each item:

1

2

3

4

5

Task orientation

Contextual information

Maintenance

Repairs

Operations

Assembly

inspection and testing

Career development

Technical documentation

DIY Guides

Education and training

Innovation and design

Customer experience

Marketing

AR technology readiness

Now we would like to know your views on the current status of AR technology.

☐

Now we would like to know your views on the current status of the technology readiness of augmented reality (AR) / wearable technologies (WT).

How technologically ready are the specific AR / WT components to be used by your customers for work activities?

Please rate from 1 = "fully ready" to 5 = "not ready at all"

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please choose the appropriate response for each item:

1 2 3 4 5

AR tracking with computer vision

3D depth sensing

AR delivery on smart glasses

AR delivery on tablets

AR delivery on smart phones

AR software platforms (e.g. Unity3D).

[]

Are there any other important components?

Please specify and rate from 1 = "fully ready" to 5 = "not ready at all"

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

[]

In your view, what is the "killer" application for Augmented Reality (AR) / Wearable Technologies (WT)?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

[]

From your perspective, what are the main technological bottlenecks (software, hardware) for exploiting Augmented Reality (AR) / Wearable Technologies (WT)?

Only if applicable: Please specify the technological bottlenecks for exploiting AR in education and training.

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

Infrastructure and AR technology acceptance in Customer organizations

*Please answer the following questions and statements based on your knowledge and views of your **customer organizations**.*

[]

Please answer the remaining questions based on your knowledge and views of your customer organizations.

Firstly, let us think about infrastructure and technology acceptance about Augmented Reality (AR) / Wearable Technologies (WT) in your customer organizations.

Please rate from 1 = "strongly agree" to 5 = "strongly disagree"

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please choose the appropriate response for each item:

1 2 3 4 5

Our customer organizations have the
resources necessary to use AR/WT

Our customer organizations have the
knowledge necessary to use AR/WT

Integration of AR/WT into customers
organizations' work processes is easy

Learning how to use AR/WT is easy for our
customer organizations

Our customer organizations need our
technical support to be able to use AR/WT

AR/WT often creates a "wow"-effect in our
customer organizations

AR/WT is often considered as a futuristic
technology by our customer organizations

Our customer organizations use AR/WT solutions because they want to be forerunners in technology exploitation

The end-users are often involved in the design process of AR/WT solutions

[]Additional comments:

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

Interoperability

[]

How important is interoperability to your customers?

Please rate from 1 = "strongly agree" to 5 = "strongly disagree"

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please choose the appropriate response for each item:

1 2 3 4 5

Interoperability is important to our customer organizations.

Our customers are worried about vendor lock-in.

Integration costs with other software systems are excessive.

There is an ecosystem of compatible products.

There is a lack of AR-accessible content.

Content re-use from the web / other media is simple.

We author content only once and then export to the different AR browsers.

We author content in situ using an AR app.

[]

What content formats do you support (learning objects, technical documentation etc.)?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

[]

What APIs (Application Programming Interfaces) do you offer?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

[]Additional comments:

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

Price value

[]

How do you see the price value of Augmented Reality (AR) / Wearable Technologies (WT) for your customers?

Please rate from 1 = "strongly agree" to 5 = "strongly disagree"

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please choose the appropriate response for each item:

1 2 3 4 5

AR/WT systems are reasonably priced
according to our customers.

At the current price, AR/WT systems provide a
good value for our customers.

[]

Who will benefit the most from the use of Augmented Reality (AR) / Wearable Technologies (WT)?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)
All your answers must be different and you must rank in order.

Please number each box in order of preference from 1 to 5

Management

Maintenance

Production

Human Resources

Research & Development

[]Only if applicable: What is the (estimated) average Payback Period of Augmented Reality (AR) / Wearable Technologies (WT) systems for your customers?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

[]Additional comments:

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

Regulations and conformance

[]

Are there regulations that affect the Augmented Reality (AR) / Wearable Technologies (WT) development?

Please rate from 1 = "strongly agree" to 5 = "strongly disagree"

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please choose the appropriate response for each item:

1 2 3 4 5

There are regulations that clearly affect the
AR/WT development.

[]If you answered 1 or 2 to the previous statement, please explain which regulations affect the Augmented Reality (AR) / Wearable Technologies (WT) development.

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

[]Additional comments:

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

Personal Background

In this section we would like to get to know some of your personal background with respect to the use of AR.

[]

What is your level of expertise with respect to using augmented reality (AR) / wearable technologies (WT)?

Please choose **only one** of the following:

I use AR/WT in my daily routine

I sometimes use AR/WT

I tried AR/WT

I have no experience in the use of AR/WT

[]What is your role in your organisation?

Please choose **all** that apply:

Trainer

Researcher

Developer

Content Creator

Other:

[]

Which devices/technologies are you using?

Please specify how often you use which device or technology:

1 - permanently | 2 - often | 3 - sometimes | 4 - rarely | 5 - never

Please choose the appropriate response for each item:

1

2

3

4

5

Smartphone

Tablet

Smart Glasses (e.g. Google Glass, Epson
Moverio)

Smart Watch

Fitness Tracker

Your organisation

Let us know a few things about the organisation you are working for.

[]How many employees does your organisation have?

Please choose **only one** of the following:

1-10

11-50

51-500

more than 500

[]In which business fields is your organisation operating?

Please choose **all** that apply:

Training Provider

University

Research organisation

AR/WT Hardware Developer

AR/WT Software Developer

Other:

Please choose the most appropriate ones or specify "other" and provide a comment.

[]Who is driving augmented reality (AR) / wearable technologies (WT) within your organization?

Please choose **all** that apply:

Management

Maintenance

Production

Human Resources

Research & Development

Customers

Other:

[]Who takes (would take) decisions concerning augmented reality (AR) / wearable technologies (WT) in your organization?

Please choose **all** that apply:

Management
Maintenance
Production
Human Resources
Research & Development
Customers
Other:

The WEKIT Community

The following questions ask about your relation to the WEKIT community.

If you are interested in further contacts, please give us your contact details. You may also name an alternative contact person within your organisation. We will only contact you, if you give us contact details here AND indicated that you are interested in further contacts or available for an interview.

[]Are you interested in further contacts to industrial training providers or training developers for augmented reality (AR) / wearable technologies (WT)?

Please choose **all** that apply:

Industrial training providers
AR/WT training developers
AR/WT solution developers
Other:

[]Do you need full-fledged solutions or are you interested in research?

Please choose **all** that apply:

Applicable Solutions (ready to deploy)
Innovative Applications (for pilots)
Research results (for initial exploration)
Other:

[]Would you be available for an additional interview from WEKIT staff?

Please choose **only one** of the following:

Yes
No

[]Which components could you contribute to the WEKIT.one Open Source Technology Platform?

Only answer this question if the following conditions are met:

Answer was 'Yes' at question '3 [ARTechProvider]' (Is your organisation developing or distributing hardware or software for augmented reality (AR) / wearable technologies (WT)?)

Please write your answer here:

[]Please name your organisation

Please write your answer here:

[]Contact person name (you or alternative contact person)

Please write your answer here:

If you are interested in further contacts, please give us your contact details. You may also name an alternative contact person within your organisation. We will only contact you, if you give us contact details here AND indicated that you are interested in further contacts or available for an interview.

[]E-Mail address (yours or alternative contact person's)

Please write your answer here:

[]Phone number (yours or alternative contact person's)

Please write your answer here:

Finally!

Thank you for your contribution!

Are you interested in learning more about WEKIT?

- Join the WEKIT Community: <https://wekit-community.org/>
- Join WEKIT on facebook: <https://www.facebook.com/WEKIT-community-1101446479900608>
- Follow WEKIT on Twitter: https://twitter.com/WEKIT_community



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 687669

Submit your survey.

Appendix A.2 – Second questionnaire

Augmented Reality and Wearables in Training and Education (version 2, concise)

Augmented reality and wearables show huge potential to change the way we educate and train. In the publicly-funded WEKIT project, we explore experience capturing to support observation of a master performing problem-solving tasks and to deliver augmented real-time guidance to trainees. With this second questionnaire, we continue to survey both past experience and future expectations of Augmented Reality and Wearable Technologies.



We would like to highlight that the survey is designed so that you can answer it even if you do not have prior experience in developing or using these technologies.

Please watch the introductory video to the left. It provides examples of real use cases of the technology as opposite to visionary and futuristic ones that can be found.

This is a unique opportunity to provide your insights and opinions as input to the development of a public technology roadmap and its implementation in an open platform.

The survey consists of 19 core questions required an answer on a Likert scale from strongly agree to strongly disagree. Towards the end, there are 4 additional questions about the respondent.

This short second version of the questionnaire takes about 5-7 minutes to complete.



This project has received funding from the European Union's

There are 10 questions in this survey

Core questions

[]Please rate the following items *

Please choose the appropriate response for each item:

	Strongl y Disagre e	Disagre e	Somewh at Disagree	Neither agree or disagre e	Somewh at agree	Agre e	Strongl y Agree
I look forward to those aspects of my job that require me to use AR & WT.							
I will always try to use AR & WT in my daily life.							
I could complete a job, if I had used similar technologies before this one to do the same job.							
My interaction with AR & WT is clear and							

understanda
ble.

I have the
resources
necessary
to use AR &
WT.

I like
working with
AR & WT.

I am
addicted to
using AR &
WT.

People in
my
organization
who use AR
& WT have
more
prestige
than those
who do not.

I use AR &
WT
solutions,
because I
want to be a
forerunner
in
technology
exploitation.

Interoperabil
ity is
important
for AR &
WT.

I am worried
about
vendor lock
in with AR &
WT.

Integration
costs of AR
& WT with

other
software
systems in
use are
high.

I would find
it useful if
my friends
knew where
I am and
what I am
doing.

Learning
curve for AR
& WT is too
high
compared
with the
value they
would offer.

With AR &
WT, I
immediately
know when
a task is
finished.

Using AR &
WT
increases
my
productivity.

AR & WT
increase
precision of
tasks.

People who
are
important to
me think
that I should
use AR &
WT.

[]Please rate the following item *

Please choose the appropriate response for each item:

	never	once a month or less	once every two weeks	3-6 times a week	once every day	several times a day
--	-------	----------------------------	----------------------------	---------------------	-------------------	---------------------------

Please
choose
your
usage
frequency
of AR/WT

Additional questions

[]What is your gender?

Please choose **only one** of the following:

- Male
- Female
- Do not want to say

[]What is your age?

Please choose **only one** of the following:

- 18 to 24 years
- 25 to 34 years
- 35 to 44 years
- 45 to 54 years
- 55 to 64 years
- Age 65 or older

[]Which kind of organisation are you working for?

Please choose **all** that apply:

- Health
- Transport
- Space
- Manufacturing
- R&D
- Education
- Other:

[]To which user group do you belong with respect to AR/WT?

Please choose **only one** of the following:

- End-User
- Manager
- Trainer
- Developer
- Researcher

Other

General Feedback

[] Please give us any additional information or feedback to the questionnaire or to augmented reality and wearable technologies in training and education.

Please write your answer here:

[] Your name

Please write your answer here:

[] Your E-Mail

Please write your answer here:

[] Are you interested in further contacts?

Please choose **all** that apply:

Inform me about project outcomes

You can contact me for follow up questions

Finally!

Thank you for your contribution!

Are you interested in learning more about WEKIT?

- Join the WEKIT Community: <https://wekit-community.org/>
- Join WEKIT on facebook: <https://www.facebook.com/WEKIT-community-1101446479900608>
- Follow WEKIT on Twitter: https://twitter.com/WEKIT_community



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Submit your survey.

Thank you for completing this survey.

Appendix B.1 – Interview Questions

Personal information

- (Name)
- (Did you fill in the WEKIT online questionnaire?)
- What is your role in this organisation, what are your duties at work?
 - o (If not clear otherwise): Please describe your organisation in terms of number of employees, field of business, innovation focus.
- What is your experience on Augmented Reality solutions generally? Work-related; other?

[Introduction video]

Current use of Augmented Reality

- Can you please describe, how is AR used in this organisation? For which purposes it is used? (Training/education, maintenance, research, other?)
- *Alternative:* Can you please describe, how is AR used in your customer organisations? For which purposes it is used?
 - o Why is it used?
 - o Who are the users of AR?
 - o Who makes the decisions concerning the use of AR?
- Are you aware of any future plans concerning the use of AR in your area *or* in your customer organisations / target groups?
 - o If yes, can you please tell about the plans?
 - o If not, can you think of any areas or work tasks that could utilise AR, and how could it be utilised?

Educational needs (*questions mainly for trainers*)

- What is the current status of Augmented Reality in your company's *or* customers' training and training programmes?
- Who makes the decisions when introducing new educational/training offers? (What is the current decision making process?)
- What kind of training and educational needs do you have *or* your customers have right now?
 - o What are the main goals of training in your area/organisation *or* in your customers? Could they be for example
 - taking the right decisions in complex situations,
 - performing tasks with highest possible precision,
 - performing tasks at highest possible speed,
 - reducing error rates?
- What kind of plans do you *or* the customers have for the future training?
 - o How could AR support these plans?

AR technology readiness

- What are the main technological problems when using Augmented Reality in your area?
- Can you imagine and describe, what would be the greatest application for AR? The 'killer' application.

- What kind of technological issues should be solved in this ‘fantasy application’?
- Are you aware of any regulations that would affect the use of AR?

Technology acceptance – performance expectancy

- Why would Augmented Reality be great for training / other purposes?
- Can you think of a situation, where AR was working very well and made the users happy? Please describe the situation and why it was good?
 - The opposite: Do you remember any bad experiences of using AR? What happened?
 - How do people in this company *or* in your customer companies like using AR for training / other purposes? Why?
- How would you justify the necessary investment for AR solutions? Why should this company *or* your customers pay for AR solutions?
 - What do you think of the current prices of AR systems?

Use case

- [Description of XX use case]: What do you think of this idea? How could it be better?

WEKIT community

- Would you be able to participate in hands-on testing with a prototype?
- Would you be interested in joining our online WEKIT community?

<https://wekit-community.org/>

[Write down interviewee contact information]

Thank you!



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